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SCIENTIFIC PROCEEDINGS

OF THE

ROYAL DUBLIN SOCIETY.

New Series.

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THE
SCIENTIFIC PROCEEDINGS
OF THE
ROYAL DUBLIN SOCIETY.

I.—ON SOME EFFECTS PRODUCED BY LANDSLIPS AND MOVEMENTS OF THE SOIL-CAP, AND THEIR RESEMBLANCE TO PHENOMENA WHICH ARE GENERALLY ATTRIBUTED TO OTHER AGENCIES. BY PROFESSOR V. BALL, M.A., F.R.S., F.G.S., Hon. Sec., Royal Geological Society of Ireland. (PLATE I.)

[Read, November 20, 1882.]

IN the year 1878 I published¹ a preliminary, and, of necessity, imperfect sketch of what, from the evidence then available, I believed to be the mode of origin of the series of lakes which occur at Naini Tal and its neighbourhood, in the North-west Himalayas.

The probable glacial origin of these unique Himalayan lakes had previously been suggested by Mr. H. F. Blanford;² but the tentative hypothesis put forward in my Paper was, that they were not true rock-basins, but were simply portions of river-eroded valleys, which had been more or less dammed up by the fall of *débris* from the slopes of the surrounding hills. So the matter was left, but not for very long, as, in 1880 my late colleague, Mr. Wm. Theobald,³ having visited the lakes, pronounced them to be glacial.

¹ Records of the Geological Survey of India, vol. xi., p. 174.

² Proceedings, Asiatic Society of Bengal, January, 1877, p. 3.

³ Records of the Geological Survey of India, vol. xiii., p. 161.

By a singular coincidence, Mr. Theobald's Paper, and the first news of the great Naini Tal landslip, reached me at the same time when journeying to India in September, 1880. My first formed intention was, provided permission were obtained, to start for Naini Tal immediately on reaching Bombay, as I concluded that the phenomena exhibited by this landslip could not fail to throw light upon the disputed question as to the origin of the lake. I found, however, that a committee had been appointed by the Government to report upon the disaster, but that the services of a geologist were not considered necessary to take part in the deliberations.¹ In due time this committee published a report which, while dealing with the lamentable destruction of life and property resulting from the landslip, did not throw much light on its cause. Fortunately, however, the appearances presented have been described by a geologist, Mr. R. D. Oldham,² who happened to be in the neighbourhood at the time. Besides giving a good description of the mode of operation of the agencies which culminate in such landslips, he adds some remarks of considerable interest which bear upon my view of the causes to which the lakes at Naini Tal and its neighbourhood owe their origin.

In spite of repeated friendly invitations by Mr. Theobald, that I should reply to his Paper, I deferred doing so while still any hope remained of my being able to make a further and more complete examination of the locality. And now, when all such hope is gone, I feel I am not in a position to add much to what has been already published; at the same time I have, since I visited Naini Tal, examined numerous undoubtedly glaciated lakes in England, Ireland, Scotland, and Switzerland, and I therefore feel increased confidence in suggesting what I believe to be the legitimate deductions to be drawn from the whole array of observed and recorded phenomena.

¹ By a strange coincidence, the author of an article on landslips, in *Nature*, dated September 30, and which was inspired by the telegraphic tidings of the landslip, wrote as follows in reference to the choice of safe ground for building:—"This is mainly a geological question, but it is evidently one of the utmost social importance. Among the staff of the Geological Survey of India there is no doubt an officer whose services could be made available to examine and report upon the structure of the ground with reference to this question."

² Records of the Geological Survey of India, vol. xiii., p. 277.

The illustrations and plans which I now exhibit will serve to convey an idea of the principal of these Himalayan lakes (Naini Tal) and its surroundings. For descriptive details of it and the others of the series I must refer to my original Paper. Here it will be sufficient, perhaps, to concentrate our attention on Naini Tal as typical, though some of the other lakes exhibit individual peculiarities indicating local modifications in form, which may possibly be connected with the irregular profiles impressed on the surface of the rocks at the time of their upheaval, and which are therefore less directly due to the effects of subærial denudation. Though often tacitly assumed, it is not, I submit, justifiable to conclude that upheavals of mountains left simply plane surfaces for the subærial forces to operate on; ridges and hollows must assuredly have been produced by such disturbances among non-homogeneous rocks.

Naini Tal occupies the bottom of a valley which runs with the strike of a variety of altered rocks, among which much contorted and splintered shales are the most prominent: there are also some limestones, generally occurring in lenticular bands, and indications of the presence of a deep-seated dyke, or dykes, of trap have also been observed.

Where the slopes are gentle the upturned edges of the shales are more or less covered by humus, which in many places supports good-sized oak and other trees. The ledges which are cut into this humus, in order to afford sites for building, serve as collecting-grounds for the drainage, and have been the principal cause of the disturbance of the equilibrium, which has resulted in the landslip about to be described, as well as of many previous ones known to have taken place in the same locality.

The facts connected with the Naini Tal landslip are the following:—On Saturday, the 18th of September, 1880, after about forty hours of continuous rainfall, during which time twenty-five inches of rain fell, at 10 o'clock in the morning a slip occurred on the north-east slope of the valley, which buried a portion of the buildings behind the Victoria Hotel, in which there were at the time some natives and a European child.

By the aid of a party of volunteers and some men from the military dépôt, all who had been buried in the ruins, and were still alive were rescued. It was then observed that a stream of

water threatened the destruction of the hotel, and the labours of all who were engaged were directed to the diversion of its course. While so engaged, the great slip came down and overwhelmed them, raising the total loss of life to about two hundred persons, of whom forty-three were Europeans.

This last fall is believed to have not occupied more than one-fourth of a minute in its descent, although several large buildings appear to have been carried along on the surface of the *debris* for some distance before they fell. The material of the fall consisted of broken, splintery shales, humus, and vegetation, which rested upon the upturned edges of a zone of much contorted and shattered shales. After settling down, the surface of the *debris* presented the following appearance:—It was about 600 yards long, of which the lower half dipped at an angle of about 15° , and the upper at from 25° up to the vertical. Owing to the immense quantity of water which had been absorbed into the mass before it began to slide, the whole was in a semi-fluid condition, which was testified, not only by the low angle of repose, but also by the fact that those who ventured upon it sunk up to the knees.

One of the principal objections urged by Mr. Theobald to my view of the origin of the barrier closing Naini Tal was, that those slips “possessed of most mobility, from the greater fluidity of their composition, are in the precise ratio of such fluidity, least capable of . . . bearing upon their surface craggy masses of rock, such as I should term erratics.”

This almost *ex cathedra* statement assumes, what is by no means necessary, that the blocks should be carried *on* the surface: and it breaks down altogether when compared with the actual fact, that this Naini Tal slip, by no means an extensive one, as compared with many others known to have occurred in the Himalayas, did carry down blocks 9 or 10 feet in diameter *in* the mass of detritus not on the surface. Heavy rainfall and streams acting on such an accumulation would, undoubtedly, produce an appearance, by the removal of the finer portions, very closely resembling that presented by ordinary moraines, and such an accumulation as that which forms the retaining barrier of Naini Tal.

It would not be difficult to further illustrate these views by reference to several famous landslips which have taken place in Switzerland, in which cases large masses of rock, together with

finer materials, have been carried down the slopes of mountains, and spread far and wide in the valleys at their bases. These examples have, however, been fully described elsewhere, so that we may, without more explicit reference to them, pass to the consideration of another variety of soil-cap movements.

SUBMERGED FORESTS.

To by far the majority of people the appearance of submerged forests or bogs in the vicinity of the coast of any land, whether continental or insular, would be accepted, without hesitation, as being indicative of subsidence. Some observers would probably be tempted, moreover, to calculate the amount of the lowering from the data so afforded. My present object is to discuss the reasons which have led me to adopt the view that such a conclusion may be wholly erroneous. Nay more, in certain cases, the existence of such submerged forests may even afford *prima facie* evidence of upheaval of the land.

I was first led to the consideration of this subject by the existence of apparently very contradictory evidence as to the alteration of levels of sea and land in the case of the Andaman Islands in the Bay of Bengal.

When visiting the Andaman Islands in the year 1868, the evidence appeared to me to favour the view that the islands were slowly *rising*. Although there were no raised coral reefs then known in the islands of this group, there were several creeks between the islands which had become more or less unsuitable for navigation. Thus the channel between the middle and southern islands is said to have been formerly navigable by large boats, though now, I believe, small boats can only go through it. Again, at the head of Port Blair there is a swampy pass containing mangroves through the hilly grounds to the opposite coast, which presents the appearance of having, at no very distant period, been a strait, dividing the South Andaman into two portions. In the more southern, but next adjoining group of islands, the Nicobars, raised coral reefs are of common occurrence, and their absence in the Andamans is certainly remarkable, and not easily to be accounted for if the view that the islands have risen be correct.

The late Mr. S. Kurz contended—from the existence of submerged portions of forests, and even of buildings which were

erected during the period of the first settlement of the islands in 1796—that they are now in a sinking condition.

Some of the trunks of trees which he observed had their roots attached to the soil, and were still *in situ*; many of them belonged to species which do not occur in the outer belt of mangroves, but in the next succeeding zone inside it, or in a zone at the foot of cliffs, in which positions there is no outer belt of mangrove swamps owing to the steepness of the shore.

On the one hand, the fact that the above-mentioned straits have become unnavigable may be due to either ordinary or extraordinary silting up. By extraordinary, I mean wholesale landslips, such as those in Patagonia, and therefore their condition might be coincident with a general subsidence. On the other hand, mere encroachments of the sea may produce appearances which would be mistaken for actual subsidence. This last may be the explanation in the case of the above-mentioned buildings, for instance.

Now, without attempting to discuss the conflicting evidence in this particular case, as further examination of the islands, especially with reference to the views put forward below, should, I think, first be made, I pass to the consideration of the general question as to the manner in which such apparently conflicting evidence may be reconciled.

The subject has already been dealt with in a Paper by Dr. Copping, which was read before the Geological Society of London last year.¹ The phenomena which he describes were observed in Western Patagonia, where the soil-cap slides downwards over sloping surfaces of rock, carrying with it not only the trees, ferns, and mosses on its surface, but also a *moraine profonde* of rocks, stones, and trunks of trees, with which the valleys and lakes become filled up.

Anticipating that subsidence might be suggested to account for some of the phenomena, he points out that the existence of raised beaches, and the traces in the rocks of stone-boring mollusca above present sea level, prove, on the contrary, that elevation has taken place. Removal by water of the lighter portions of the material thus brought down leaves a remnant of blocks, which are often perched on one another in a similar manner to those which

¹ Quarterly Journal of the Geological Society, vol. xxxvii., 1881, p. 245.

have been transported by glaciers; and in the particular region in question there are such glacial moraines conveniently situated for comparison.

These appearances were contrasted with those of the celebrated stone rivers of the Falkland Isles, which Sir Wyville Thompson¹ has attributed to the movements of the soil-cap, which has in part derived its motion from the expansion and contraction of the spongy mass, due to varying conditions of moisture and comparative dryness.

Several speakers, when discussing Dr. Coppinger's Paper, afforded testimony as to the probability of such a cause being capable of explaining many accumulations of blocks and breccias in both recent and early times, while Sir John Hawkshaw showed that movements of the soil-cap, and with it of rocks, were only too familiar to engineers, and that, in some cases, they continued for many years after once the surface had been disturbed.

In this instance of Patagonia, then, we have a beautiful example of the contemporaneity of two apparently contradictory phenomena—(1) a rising of the general mass of the land; and (2) a subsidence of the soil-cap. Generalizing from this, it would perhaps be not too much to say that, given certain relationships between tracts of land and their soil-caps, an upheaval, owing to the disturbance of equilibrium, would invariably be followed by a subsidence of the soil-cap. Detrital matter which had settled down at its angle of repose must, on the elevation of its sustaining surface, find a new position at a lower level, and thus I believe may, in some cases, be explained the presence of submerged forests and bogs on the one hand, and accumulations of glacial-like *debris* on the other.

In regions where there is a heavy rainfall, and also in those where the protecting effects of vegetation have been removed by the cutting down of forest, subsidences of the soil-cap, as is well known, are of common occurrence without any necessary exhibition of regular landslips. There are tracts in the Himalayas where, at the cost of the primeval forests, tea-gardens have been established on the slopes, and where, after a few years, the tea-

¹ Voyage of the Challenger—*The Atlantic*, vol. ii., p. 245.

bushes have been left starving on the almost bare rocks owing to the subsidence of the soil into the valleys.

It is far from my intention to make any sweeping, or general application of these agencies, to account for accumulations of rocks in different geological periods for which a glacial origin is generally claimed. My object is to draw the attention of geologists to them, as their potency is, perhaps, not so fully recognized as it should be.

I do not profess to be an anti-glacialist; but where so much depends upon the fact of glacial epochs having existed during different geological periods, it seems to be due to the physicists that geologists should use the very utmost caution in the matter.

Here I would refer to a case where there appears to me to be fairly presumptive evidence of the existence of a glacial epoch at so early a geological period as the Cambrian. Recently, at Gairloch, in Rosshire, I examined the varied traces of the operations of the glacial period in that neighbourhood, and while doing so I was impressed with the belief that certain Cambrian breccias lying in valleys, scooped out of the surface of the Laurentian rocks, afforded evidence from their position, much more than from their lithological constitution, of the existence of a glacial period in those early times. Modern glacial action appears to have re-scooped the valleys which must have already been in existence when the breccias were deposited, and therefore it may be argued that they were originally carved out by the same tools. This is of course not quite conclusive, as it would be if, in support of it, glaciated surfaces were found underlying the Cambrians; but as yet I am not aware that any such have been discovered at Gairloch.

DESCRIPTION OF PLATE I.

Naini Tal landslip of the 18th September, 1880, from a photograph.



II.—ON THE PRESSURE OF EARTH AGAINST A RETAINING WALL. BY ARTHUR HILL CURTIS, LL.D., D. Sc.

[Read, June 19, 1882.]

WHEN a mass of earth is supported by a wall, it is an important matter to determine what the stability of the wall should be in order that equilibrium should be maintained. To solve this problem, it is necessary to determine the magnitude of the pressure and the point of its application.

The investigation which determines the magnitude of the pressure is based on a principle due to Coulomb, in accordance with which we suppose that the mass of the earth which presses against any portion of the wall, measured from the top downwards, seeks to lower its centre of gravity by sliding along some plane inclined to the horizon, at an angle not less than the angle of friction (or *repose*) of earth on earth, and compute the *horizontal* force which will be sufficient to prevent this tendency taking effect along the plane which requires the *greatest possible* resistance to counteract it. The force thus obtained is equal and opposite to the greatest pressure which can result, and is thus, in one sense, a maximum, but yet it is the minimum force which will ensure equilibrium, on the supposition that the wall is perfectly rigid.

The problem in the case in which the surface of the earth is in the form of a cylinder round a horizontal line parallel to the top of the wall, which is supposed to present a vertical surface to the earth, is solved by a theorem due, I believe, to Dr. Hart, Vice-Provost of Trinity College, Dublin: this theorem is as follows:—

Let a vertical plane $OADB$ (fig. 1) be drawn perpendicular to the wall at a point A , situated on the horizontal line coinciding with the top of the wall, and bisecting a unit of its length—one foot, suppose: let this plane cut the surface of the earth in the line $AZDB$, and at any point C on OA ; let CB be drawn inclined to the horizon at the angle ϕ , the angle of friction of earth on earth; then, if CD be drawn in such a way that, drawing DE perpendicular to CB , the area $CAZD$ shall be equal to the area CDE , the

prism whose mean section is $CAZD$, and whose height is one foot, will contain the mass of earth which, by tending to slide (along CD), would produce the maximum pressure on the portion of the wall measured by CA , while the horizontal force necessary to prevent this tendency taking effect is in *lbs.* weight equal to $62.5 \rho DE^2$, where ρ denotes the specific gravity of earth. It is not possible, of course, to apply this theorem until the form of the line $AZDB$ has been assigned.

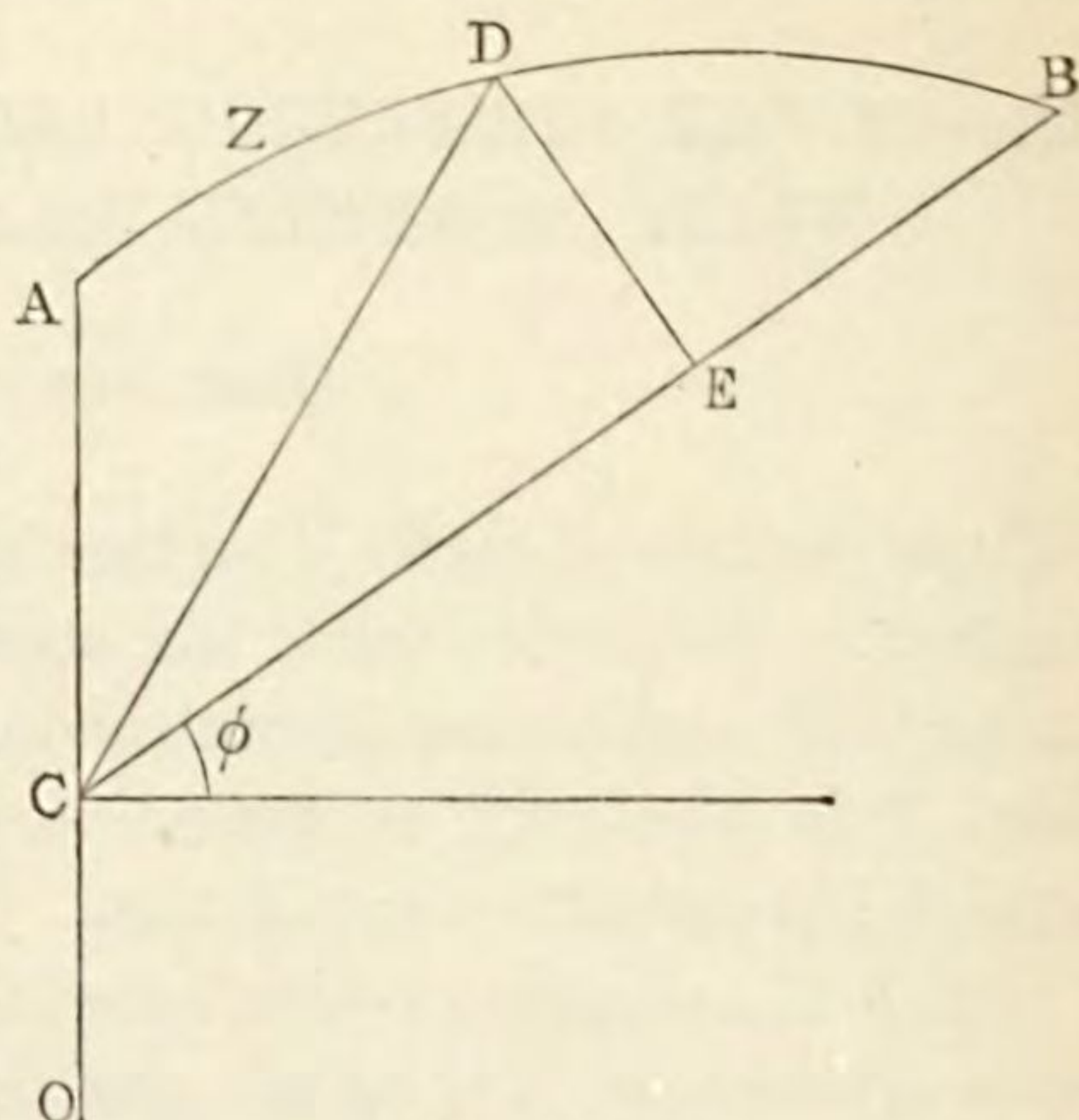


Fig. 1.

It must here be mentioned, that one of the ablest mathematicians of our time, himself an engineer, Professor Rankine, has taken exception to the assumption that the pressure of earth is perpendicular to the supporting wall, and maintains that it is inclined to it at a constant acute angle. It may be remarked, however, that the force can be supposed to be inclined to the wall at an acute angle, only on the supposition that the friction of the earth against the wall is taken into account; but, as the mathematical solution only gives us the least horizontal force consistent with equilibrium, and as, in the construction of the wall, it would be unsafe to limit its power of resistance to this minimum value, it would not, in practice, be safe to allow, in addition, a margin on account of taking into consideration the friction between the earth and the wall.

If, however, Professor Rankine's hypothesis be assumed, the consideration of the problem, when thus modified, leads, in accordance with Coulomb's principle, to a theorem differing but little from that given by Doctor Hart.

Let (fig. 2) a vertical plane, perpendicular to the surface of the wall—supposed, for greater generality, to be inclined to the vertical at an angle α —cut the surface of the wall in the straight line ACO , and the surface of the earth in the line $AZDB$; through C , any point on the line ACO , draw CF horizontal, CB inclined to CF at the angle ϕ , the angle of friction of earth on earth, and CD a

Now we must determine β so as to make P maximum or $dP = 0$, which gives

$$\frac{dW}{W} + (\cot(\beta - \phi) - \tan(\gamma - \beta)) d\beta = 0;$$

but, denoting CD by r , we have, *geometrically*,

$$dW = -g\rho \frac{r^2}{2} d\beta:$$

substituting this value for dW , we obtain $g\rho \frac{r^2}{2} \sin(\beta - \phi) \cos(\gamma - \beta)$
 $= W(\cos(\beta - \phi) \cos(\gamma - \beta) - \sin(\beta - \phi) \sin(\gamma - \beta)) = W \cos(\gamma - \phi),$ (1)

or

$$g\rho \frac{r^2}{2} \sin(\beta - \phi) \cos\{(\alpha + \phi') - (\beta - \phi)\} = W \cos(\alpha + \phi'),$$

or

$$g\rho \frac{r^2}{2} \sin(\beta - \phi) \{\cos(\beta - \phi) + \sin(\beta - \phi) \tan(\alpha + \phi')\} = W.$$

If, then, we suppose CD to be the line which solves the problem, W will denote the weight of the cylinder of earth, of length one foot, whose mean section is the area $AZDC$, so that $W = g\rho$ area $AZDC$; and, if we draw DM perpendicular to CB , and DE inclined to DM at the angle $\alpha + \phi'$, the area

$$\begin{aligned} CDE &= \frac{1}{2} DM \cdot CE = \frac{1}{2} DM (CM + ME) \\ &= \frac{r}{2} \sin(\beta - \phi) r \cos(\beta - \phi) + r \sin(\beta - \phi) \tan(\alpha + \phi'); \end{aligned}$$

therefore area $AZDC =$ area CDE , and therefore the line CD , which solves the problem, is such that, drawing DE inclined to CB at the complement of the angle $\alpha + \phi'$, area $AZDC =$ area ADE , while

$$P = \frac{W \sin(\beta - \phi)}{\cos(\gamma - \beta)};$$

or, by equation (1),

$$\begin{aligned} &= \frac{g\rho r^2 \sin^2(\beta - \phi)}{2 \cos(\gamma - \phi)} = \frac{g\rho r^2 \sin^2(\beta - \phi)}{2 \cos(\alpha + \phi')} \\ &= \frac{g\rho}{2} \cos(\alpha + \phi') \left\{ \frac{r \sin(\beta - \phi)}{\cos(\alpha + \phi')} \right\}^2 \\ &= \frac{g\rho}{2} \cos(\alpha + \phi') DE^2. \end{aligned}$$

Through C (fig. 6) draw the line CT inclined to the vertical line CA at the angle ϕ ; then

$$CT = H \sec \phi, \text{ and } AT = \{LT^2 + AL^2\}^{\frac{1}{2}} \\ = \{H^2 \tan^2 \phi + h^2\}^{\frac{1}{2}};$$

$$\therefore P = \frac{g\rho}{2} (CT - AT)^2.$$

If, then, we cut off

$$TV = AT, \quad P = \frac{g\rho}{2} CV^2;$$

so that, if we construct the locus of V , the force on the portion of the wall, measured by any line AC , will be obtained by drawing through C a line inclined to the vertical at the angle ϕ to cut the locus of V , and the force P will be proportional to the square on CV , which may be denoted by z .

This locus is easily obtained, as follows:—let LB be axis of Y , and LC axis of X ; let x and y be the co-ordinates of point V ; then

$$QT = x \tan \phi = \mu x,$$

and

$$h^2 + (y + \mu x)^2 = AT^2 = TV^2 = x^2 \sec^2 \phi = (1 + \mu^2) x^2;$$

$$\therefore x^2 - y^2 - 2\mu xy = h^2,$$

an equilateral hyperbola whose asymptotes are defined by

$$x^2 - y^2 - 2\mu xy = 0,$$

or

$$y + \tan \left(\frac{\pi}{4} + \frac{\phi}{2} \right) x = 0,$$

and

$$y - \tan \left(\frac{\pi}{4} - \frac{\phi}{2} \right) x = 0.$$

We are concerned, however, only with the portion of the hyperbola which lies within the trapezium.

To determine the point of application of the force P , extended to the entire height of the wall measured by AO ; let O be taken for origin, and the axes of X and Y vertical and horizontal; then, if x_1 denote the abscissa of the point of application of P , while x represents the abscissa of any point U , and dP the elementary pressure on a portion of the wall measured by dx , then affecting with a suffix each quantity relating to the point O , $P_1 x_1 = \int x dP$

$= xP - \int Pdx$; but, at O , $x = 0$, and, at A , $P = 0$; therefore, xP vanishes at each limit, and $\therefore$, as $P = g\rho z^2$, $z_1^2 x_1 = - \int z^2 dx$; but dA , the area of UW , any element of the parabola contained between the curve, the element dx , and the lines through its extremities parallel to z , is equal to $-z \sin \phi dx$, while $\bar{z}$, the ordinate of the centre of gravity of this element, $= \frac{z}{2}$; therefore

$$z_1^2 x_1 \sin \phi = - \sin \phi \int z^2 dx = \int z dA = 2 \int \bar{z} dA = 2A\bar{z}_1,$$

or

$$x_1 = \frac{2A\bar{z}}{z_1^2 \sin \phi}.$$

As a verification of this result, let h vanish; the hyperbola then reduces to its asymptotes; the branch AV becomes the straight

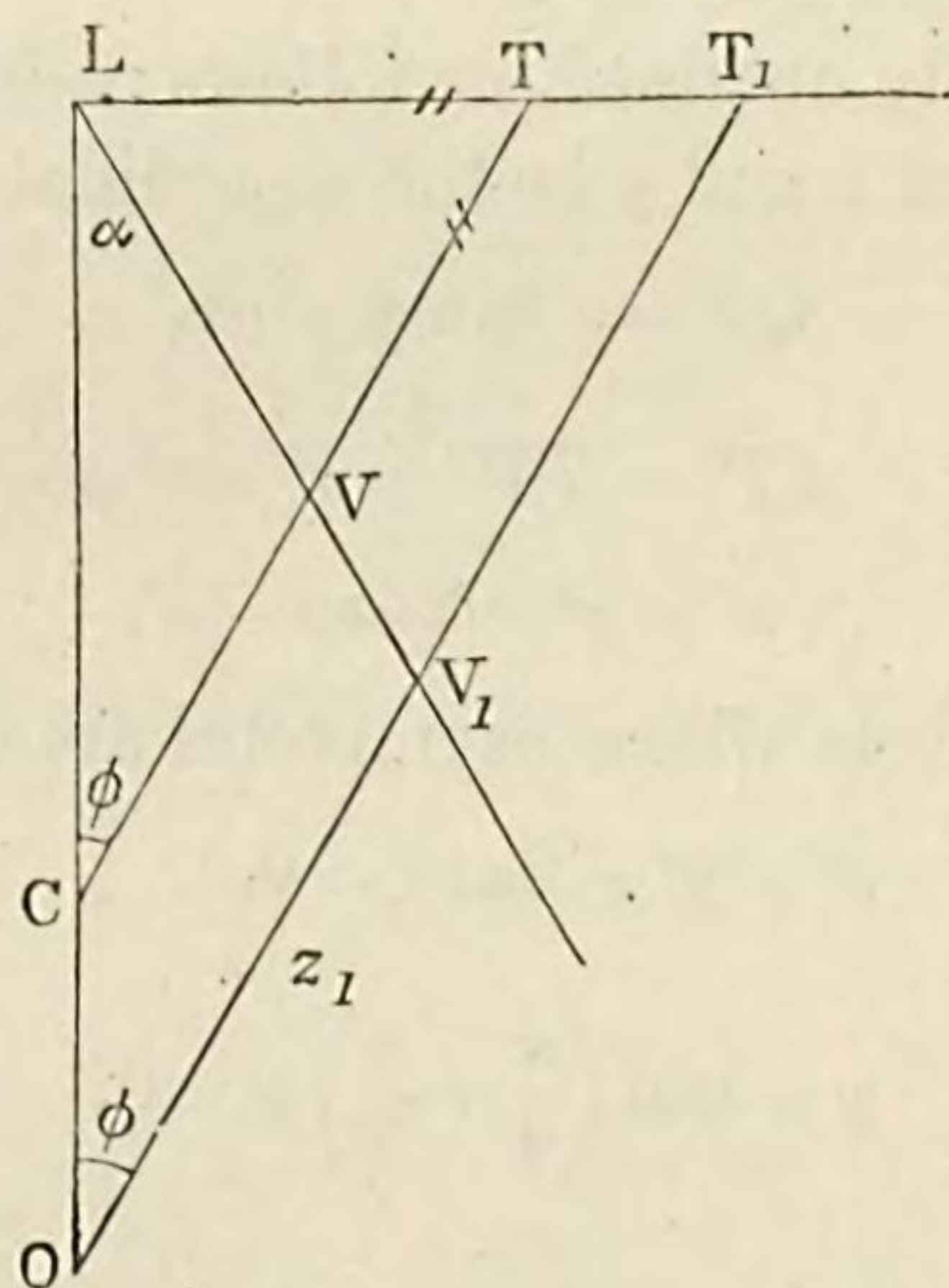


Fig. 7.

line through A , making, with the vertical, the angle $\frac{\pi}{4} - \frac{\phi}{2}$ (this also appears geometrically; for, if (fig. 7)

$$\begin{aligned} VT = AT, \quad \phi + a = \angle AVT &= \frac{1}{2} \left\{ \pi - \left(\frac{\pi}{2} - \phi \right) \right\} \\ &= \frac{\pi}{4} + \frac{\phi}{2}, \quad \text{and } a = \frac{\pi}{4} - \frac{\phi}{2}; \end{aligned}$$

but

$$2A = H_1 z_1 \sin \phi, \quad \text{and } \bar{z}_1 = \frac{z_1}{3};$$

therefore,

$$x_1 = \frac{H_1 z_1^2 \sin \phi}{3 z_1^2 \sin \phi} = \frac{H_1}{3}, \text{ as it ought.}$$

I may remark that Moseley, in his *Engineering*, has investigated, by a different method, the problem where the friction between the wall and the earth is neglected, and has deduced, in certain cases, analytical expressions for the pressure. These expressions may also be deduced from the geometrical solutions given in this Paper, but, as they are not logarithmic, they are practically of little value, and, I think, in practice, are of little importance compared with graphic methods and geometrical constructions.

It has been objected to such discussions as the above, that, after the solution has been obtained on mathematical principles, it is necessary to introduce a factor of safety, to ensure stability, making the wall from eight to ten times as strong as is in accordance with the theoretical result; but this objection is equally valid against the application of mathematics to all cases where the strength of materials is concerned, in which, as stated by Rankine, Twisden, and others, it is usual to take the working stress as one-eighth, or one-tenth of the proof stress, which is itself considerably short of the ultimate strength. If a wall could be made perfectly rigid, and would not in time become weakened if taxed to its ultimate strength, then the mathematical deductions would in practice be exact.

III.—ON GEARING FOR BICYCLES AND TRICYCLES. BY
 GEORGE JOHNSTONE STONEY, D. Sc., F. R. S., AND
 GEORGE GERALD STONEY.

[Read, December 18, 1882.]

THE making of Bicycles and Tricycles has become an enormous industry, and the pecuniary value of patents affecting paltry details, if they can be brought largely into use, is consequently great. The bicycle industry is so overloaded with patents of this kind that no purchaser can obtain a machine with every improvement which he may reasonably desire, and the best makers are very much hampered. The inconvenience to the public in this case, which accompanies benefit to a few, has suggested to us that it may be of advantage to communicate the three following contrivances to the Royal Dublin Society, with a view to rendering them incapable of being made the subjects of patents.

We have been impressed very much with the advantage of a small wheel in mountain rides, which are those which we chiefly practise. But on the other hand, when one comes down into the plain, the small wheel becomes unsatisfactory, as it prevents the rider attaining the speed which would otherwise be his natural pace under those easier circumstances. We have hitherto ridden machines of a size selected with a view to strike a compromise between these opposed requirements, but a much better result would be obtained if we could get a wheel which would become small and powerful on the hills, and large and swift in the level country. A wheel which could be geared to two or more speeds presents the same advantages. And there are two ways in which we should propose to accomplish this. In both we should prefer a very small wheel, say of 36, or at most 40 inches diameter, to be driven level, as the technical phrase is, that is, ungeared when climbing up hills, and to be geared up so as to furnish a higher speed on easy ground.

I. The first of these contrivances is adapted to a machine with some such levers as the 'Xtraordinary' and the 'Facile.' The hub of the bicycle wheel is to be made tubular, for the purpose of

allowing an inner axle, to which the cranks are keyed, to run freely within it. To one side of the hub a sun-wheel is fixed, into which a planet-wheel, mounted on a pin near the end of one of the cranks, is to work. If this planet-wheel be fastened to the crank so as to form one solid piece with it, the machine will be geared level in the way that is suited to hill-work. In this case the wheel of the machine, with its sun-wheel attached, the crank and the planet-wheel will all form one solid mass, which will turn together without any relative movement. On the other hand, if the planet-wheel is fastened to the lever or connecting-rod of the bicycle, it will continue to be carried round by the crank, but will be kept from turning round with it, and accordingly it will drive the sun-wheel at a speed which is determined by the numbers of teeth in the sun and planet-wheels, and which can be made whatever the maker pleases. A proper appliance should be provided, which will enable the rider at will to connect the planet-wheel either to the crank or the lever, and he can thus drive his machine level when he connects the planet-wheel with the crank, or geared up when he connects it with the lever.

II. The next contrivance is one for attaining the same end, and is suited to machines with levers something like those of the 'Facile.' Cogged wheels are to be keyed on both ends of the axle of the bicycle wheel; each of these is to work into a cogged wheel placed immediately above it, and running on a pin screwed firmly into the fork of the bicycle. Each of these cogged wheels is to be provided with a pin projecting from its face, over either of which the connecting-rod from the lever may be hooked. If the connecting-rod is hooked to the lower wheel it will drive the machine 'level,' and the upper cogged wheel will run as an idle wheel, doing no service, but doing no harm. If, on the other hand, the rider hooks the connecting-rod to the upper cogged wheel, his foot will drive that cogged wheel, which in turn will drive the lower one, and with it the bicycle wheel to which it is attached. The number of teeth in the wheels will of course then determine the speed.

It would be a great convenience if the rider could alter the gearing without dismounting; and this might be effected if connecting-rods hung permanently from both the wheels, with a cross-rod joining their lower ends. This cross-rod should pass through an eye attached to the lever on which the foot works, and should

be capable of slipping from end to end through that eye, and of being held to that eye in either of these two positions. When the cross-rod is slipped to one end of its range the foot would work the lower of the cogged wheels, and would drive the machine level, and when the rod is slipped to the other end the foot would work the other cogged wheel, and would drive the machine 'geared up.' The slipping of the cross-rod could be effected by continuing the longer of the connecting-rods upwards so as to bring it within reach of the rider, and by providing spring-clutches to hold the cross-rod in its place when it has been slipped to either end.

The third contrivance is one which we described at a former meeting of this Society, and which we would ask leave to describe again with a view to its being placed on record. It is a contrivance for applying balance gear to a *cranked* axle. Balance gear—that is, gearing which allows the driving wheels of a tricycle, traction-engine, &c., to travel at unequal velocities while both continue to be driven—has hitherto been applied to a straight axle lying between those wheels. We wish to point out that it may be applied to a cranked axle, so that it is possible to apply it to a tricycle, the main axle of which is to be acted on directly by the feet—an arrangement which we believe would in many cases be preferable to the method hitherto employed of adding a countershaft for the feet to work on. This we propose to do as follows:—The cogged

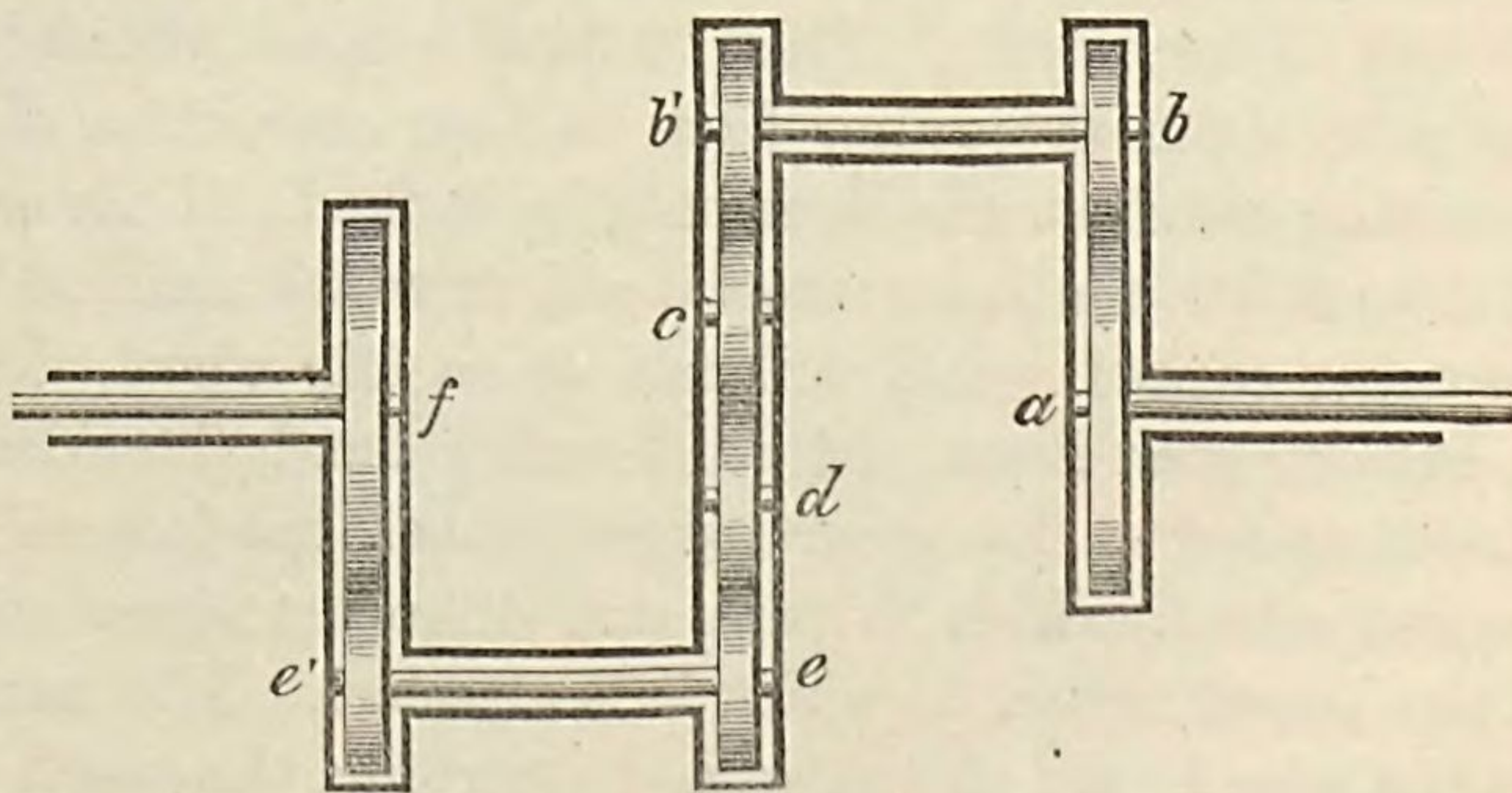


Fig. 1.

wheel *a* is keyed to the axle of one of the driving wheels of the tricycle. *a* acts on *b* and *b'*, cogged wheels keyed to an axle passing through a tube on which the right foot acts. *b'* acts on *c*, *c* on *d*, *d* on *e* and *e'*, keyed to an axle passing through a tube on which

the left foot acts, and finally e' on f , which is keyed to the axle of the second driving wheel of the machine. The intermediate wheels c and d are introduced only to make the arrangement more compact. If abundant space can be allowed, these intermediate wheels may be dispensed with by making b' and e large enough to act directly on one another.

The balance gear here described might, perhaps, sometimes with advantage, be applied to the countershaft of the machines which are provided with a countershaft.

In all cases where balance gear is employed, we wish to point

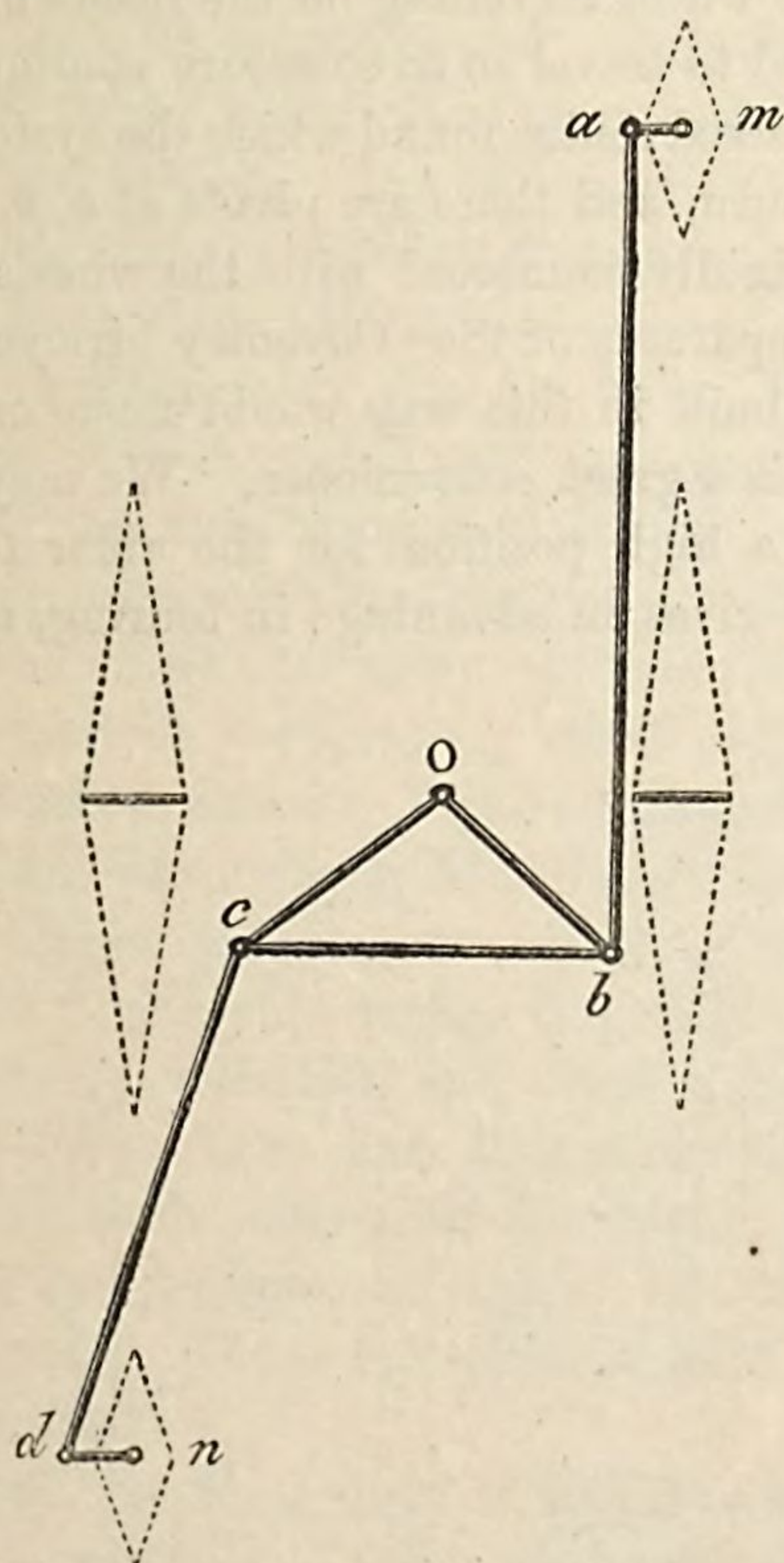


Fig. 2.

out that the machine may be guided by adequate breaks which may be applied to one or other of the driving wheels at will. We have found wood a good material for powerful breaks which are to act upon the rubber of a wheel.

A machine provided with the balance gear and guiding arrangements we propose might have the rider's weight brought almost entirely over the driving wheels, in which case his position might be made secure by two safety-wheels mounted like castors, one in front of one driving wheel, the other behind the second driving wheel. Or perhaps better still, the lever which applies the break might be made to act on connecting bars which would at the same time give the proper inclinations to the two safety-wheels. One arrangement for accomplishing this is represented in the adjoining figure. It would, as in Blood's patent, give a greater inclination to the wheel travelling on the inside of the curve along which it is desired to travel so as to secure continuous rolling. In the figure, *O* is a fixed centre round which the system of connecting-rods is made to turn, and there are pivots at *a, b, c, d*: *ma* and *nd* are projections rigidly connected with the wheels to be guided, as in the guiding apparatus of the 'Coventry' tricycle.

A tetracycle built in this way would make only two tracks on the road, which is a great convenience. We may observe that we have not found a high position for the rider to be a source of danger; while it gives an advantage in touring, and looks better.

IV.—VELOCITY AND ENERGY OF SMALL SHOT. BY JOHN RIGBY, M.A.

[Read, February 19, 1883.]

THE Velocity of projectiles, and the laws which govern the resistance of the air, have been investigated by various methods. Robins, in 1742; and Hutton, in 1790, with the aid of the ballistic pendulum, made considerable progress in determining them in the case of spherical balls of moderate size. Between 1839 and 1848 experiments with larger spherical shot were made at Metz, by Piobert, Morin, and Didion. The introduction of electrical apparatus for measuring short periods of time gave a fresh impulse to these researches, and since 1860 a vast amount of work has been done by British artillerists in this direction. The development of rifled ordnance and elongated shot enlarged the scope of the inquiry. In 1865 the Rev. Francis Bashforth, then Professor of Mathematics to the Advanced Class of Artillery Officers, constructed a chronograph, which bears his name, and gave satisfactory records of the successive periods occupied by rifled projectiles in passing the intervals between ten screens, placed at distances from each other of 150 feet.¹ With rare industry Mr. Bashforth has reduced and tabulated the results of experiments extending over sixteen years, and his Tables of Coefficients render it possible to calculate the trajectories, remaining velocities, and times of flight of projectiles of most of the various forms and dimensions likely to occur in practice. The Tables for computing the remaining velocities, &c., of Ogival-headed shot embrace all initial velocities from 100 to 2900 feet per second.² Those for spherical shot range from 500 to 1900 feet per second.

It is unfortunate that no law can be found to express the resistance of the air to a projectile in terms of the velocity. For Ogival-headed elongated shot it is stated by Bashforth to vary roughly

¹ *Vide* A Mathematical Treatise on the Motion of Projectiles. By Francis Bashforth, B.D., &c. Asher & Lee, 1873.

² *Vide* Final Report of Experiments with the Bashforth Chronograph. W. Clowes & Son, 1880.

as the sixth¹ power of the velocity when this lies between 900 and 1100 f. s.; to vary as the third power from 1100 to 1350 f. s.; and for velocities above 1350, to vary as the second power, which is the Newtonian law, based on the supposition that the shot is at every moment penetrating an undisturbed medium, a supposition which only holds for velocities greater than the velocity of sound. This remarkable change in the law of resistance, when the velocity passes a certain limit, was early discovered by Robins and Hutton. Under these circumstances Mr. Bashforth has chosen to express the resistance of the air by the help of a variable coefficient and the third power of the velocity; and as it has been found that the effect of the resistance at a uniform velocity varies as the square of the diameter divided by the weight, it is easy to apply the Tables to shot of various dimensions by substituting the particular value of $\frac{d^2}{W}$ in each case.

As the experiments with the Bashforth Chronograph were carried out with guns varying from 3 inches to 9 inches diameter, and with shot varying from 6 lbs. to 250 lbs. weight, their application to small arms must be taken as an approximation only, since there are in the latter case modifying conditions, the effects of which cannot be predicted.

In the case of spherical shot, however, as experiments made with musket bullets have been found to give results which apply to large guns, it is fair to conclude that the Tables calculated from the latter may, with sufficient truth, be applied to spherical projectiles of diameters much smaller than musket balls, such as the small shot used in fowling-pieces; and it is more particularly to the movement of such small projectiles that I wish to direct attention.

In 1878, Mr. J. H. Walsh, the ingenious editor of the *Field* newspaper, dissatisfied with the tests then in use, devised a kind of recoiling target, which he named a "force gauge," for the purpose of measuring the force with which the pellets in a charge of shot struck the mark at a certain distance. Up to that time very vague ideas were held as to the actual velocity of the charge propelled from shot guns. One writer in the *Field* placed it as low as

¹ This statement is modified subsequently. See Final Report, p. 4.

550 feet per second, while an expert, who had published several books on guns, affirmed that the mean velocity of the charge in the first 40 yards was 1200 feet per second.

In this state of the question I determined to measure, by means of the "Boulengé" chronograph, the actual time of flight for 120 feet from muzzle. To enable me to do so, one of those instruments was placed at my disposal by Messrs. Pigou, Wilks, and Lawrence, the eminent gunpowder manufacturers at Dartford, and I found their apparatus quite suited to the purpose. The interval was measured between the rupture of a fine wire stretched across the muzzle, and the movement of an iron target hung on an axis, in such a manner that the impact of a considerable portion of the charge was necessary to effect the interruption of contact. In this way the velocity of the average pellet in the charge was more nearly approached than if the second interruption had been made by a single pellet, which might have a velocity considerably above the average of the whole charge.

Since this Paper was commenced a communication has appeared in the *Field* from the pen of Major M'Clintock, giving results of numerous experiments made at the Enfield factory on the velocity of small shot.

Major M'Clintock has also used the Boulengé chronograph, but has rendered his results less satisfactory by employing as his second screen the frame with wires stretched over it, which is commonly used when the velocities of rifle bullets are investigated. He confesses that his results are affected by this obvious error, and that it is a matter of chance altogether whether the current at the second screen is interrupted by the quickest or by the slowest pellet in the charge.

The series of shots fired by me at Dartford gave the velocities in the following Table as those of the respective charges of shot at sixty feet from the muzzle. I am entitled to state this, because, although the chronograph only gives the time taken by the shot to traverse the observed interval, it has been shown that if the resistance of the air varies as V^3 , the velocity at the middle point of a short range is denoted by dividing the range in feet by the time in seconds.

As therefore it has been proved experimentally that the resistance does vary approximately as the cube of the velocity, I am

justified in accepting the mean velocity in the range of 120 feet to be the actual velocity at 60 feet from muzzle.

VELOCITIES at 60 feet from Muzzle of various Charges of Shot, observed May 6th and 12th, 1879.

[The figures are the averages of four shots in each case.]

Gauge of Gun.	Powder.		Shot.		May 6.	May 12.	Remarks.
	Drams.	Size of grain.	Oz.	No.	Ft. per second.	Ft. per second.	Length of gun barrel.
12	$3\frac{1}{2}$	No. 4	$1\frac{1}{8}$	6	847	861	30 in.
"	$3\frac{1}{4}$	"	$1\frac{1}{8}$	"	—	839	"
"	$3\frac{1}{2}$	"	1	"	—	850	"
"	$3\frac{1}{4}$	"	1	"	—	838	"
"	3	"	$1\frac{1}{8}$	"	834	—	"
"	3	No. 3	$1\frac{1}{8}$	"	827	—	"
"	$3\frac{1}{4}$	" 4	$1\frac{1}{8}$	4	—	864	"
"	$3\frac{1}{4}$	" 4	$1\frac{1}{8}$	8	—	761	"
"	$2\frac{1}{2}$	"	1	6	812	—	"
"	$2\frac{1}{2}$	"	$1\frac{1}{8}$	6	750	—	"
20	$2\frac{1}{2}$	"	$\frac{7}{8}$	6	—	828	"
"	2	"	"	"	—	734	"
"	$2\frac{1}{2}$	"	1	6	768	—	28 in.
"	2	"	1	"	711	—	"

From these velocities can be calculated by Bashforth's Tables what are the muzzle velocities and the final velocities at 120 feet, 180 feet, &c. For this purpose, however, it is necessary to determine the diameter and weight of the individual pellet whose movement one wishes to examine, and also to assume that on leaving the muzzle it is circumstanced, as to the resistance of the air, as if it were the only one in the charge, and also spherical. In practice the resistance to each pellet near the muzzle is modified by the contiguity of others, whereby the sum of all the resistances is reduced; but as want of true sphericity would increase the effect of

air resistance, these sources of error may balance one another to a considerable degree.

The measurement of the diameter and weight of small shot of various sizes, which are designated by the trade numbers of 1, 2, 3, 4, &c., is rendered troublesome by the fact that the British makers seem to have selected their size at random, and no two makers agree as to the exact weight of pellet to which they give any particular number. In America, the firm of Tatham and Brothers has adopted a more satisfactory plan, and instituted an "American Standard." They take the diameter of their largest dropshot as $\cdot 23$ of an inch, which gives twenty-four pellets to the ounce, and manufacture twenty-one sizes, each successive number being $\cdot 01$ less in diameter than the preceding, until their fine dust-shot is reached, at a diameter of $\cdot 03$; in addition to which, they make an extra-fine size, with diameter of $\cdot 015$, and weight of 84020 to the ounce. For convenience of computation, I have taken three of their sizes, viz. :—

No. 1,	diameter	$\cdot 16$,	weight	$\frac{1 \text{ oz.}}{71}$.
No. 7,	„	$\cdot 10$,	„	$\frac{1 \text{ oz.}}{291}$.
No. 9,	„	$\cdot 08$,	„	$\frac{1 \text{ oz.}}{568}$.

These represent the first, heavy shot used for wild-fowl; the second, the shot in most general use, and called No. 6 by English makers; and the third, snipe-shot (Nos. 8 or 9, English).

The values of $\frac{d^2}{W}$ for these sizes are, respectively,

No. 1, 29.08. No. 7, 46.56. No. 9, 58.16.

If I now select from the observed velocities of the medium-sized shot at 60 feet, 840 f. s., as a representative one for the ordinary charge of a good gun, and calculate by the Tables the remaining velocities at intervals of 60 feet, we get the following :—

American No. 7 shot, 291 to the oz., . . . W = $\cdot 000215$.

Velocity at muzzle,	1270 f. s.	Energy.
„ 20 yards,	840 „	2.36 lbs.
„ 40 „	634 „	1.34 „
„ 60 „	509 „	0.86 „

Now, assuming that equal weights of shot of different sizes acquire the same muzzle velocities, we get for—

$$\text{No. 1 shot} = 71 \text{ to the oz.}, \quad . \quad . \quad W = \cdot 000887.$$

Velocity at muzzle,	1270 f. s.	Energy.
„ 20 yards,	956 „	12.49 lbs.
„ 40 „	777 „	8.24 „
„ 60 „	654 „	5.84 „
„ 80 „	565 „	4.35 „
„ 90 „	529 „	3.82 „
„ 100 „	497 „	3.37 „

Again, for—

$$\text{No. 9 shot, 568 to the oz.}, \quad . \quad . \quad W = \cdot 000011.$$

Velocity at muzzle,	1270 f. s.	Energy.
„ 20 yards,	777 „	1.03 lbs.
„ 40 „	565 „	·545 „
„ 45 „	529 „	·478 „
„ 50 „	497 „	·422 „

The computed velocity here obtained for No. 9 at 20 yards is ·16 f. s. in excess of the velocity at that distance of the smallest size English shot used in my experiments. This is probably due to the smaller shot encountering more friction in its passage through the barrel, and so losing muzzle velocity. We may conclude, therefore, that the results obtained above for various-sized shots rather under-estimate the differences of velocity between equal weights of large and small shot propelled by same charge of powder.

The velocity of 634 f. s., at 40 yards for No. 7, was found to agree closely with the results of a calculation made from the observed motion of the Field Force Gauge when struck by the shot at that distance.

From an examination of the remaining velocities and energies in these Tables, the great advantage of using heavy shot for long range is very apparent. Starting at 1270 f. s., the No. 7 shot has at 40 yards lost half its speed, and at 60 is reduced to $\frac{2}{5}$ ths. The No. 1 retains half to nearly 60 yards, and $\frac{2}{5}$ ths to nearly 100 yards. The No. 9, on the other hand, is reduced to half at 32 yards, and to $\frac{2}{5}$ ths at about 48 yards. The contrast between the energies

remaining at 40 yards is still stronger, No. 1 having at that distance seven times the energy of No. 7, and fifteen times the energy of No. 9. And, again, the energy of a pellet of No. 1 at 100 yards is equal to that of one of No. 7 at 10 yards from the muzzle.

This consideration of the action of single pellets must not, however, be taken as proof that the killing power of equal charges of these different sizes of shot varies in the same proportion as these energies. That might obtain if the game were struck by an equal number of pellets in each case; but, in fact, the number striking at a given distance is proportional to the number in the whole charge, and is in inverse proportion to the weight of each pellet.

To illustrate this, take the extreme sizes, No. 1 and No. 9, in which the diameters are as 2 to 1, and the weight as 8 to 1. At 20 yards the energies of the individual pellets are as 12·49 lbs. to 1·03—say as 12 to 1—but the number of pellets in the charge of No. 9 being eight times greater than that in the charge of No. 1, for each pellet of the latter eight of the former will strike a given area, and the *total* energy expended on it is as 12·49 to 8·24, or as 3 to 2 only. At 40 yards, however, the pellet energies are as 8·24 to ·545—say 15 to 1—and the total striking energies on a given surface as 8·24 to 4·36—say as 2 to 1. We see, then, how pronounced is the advantage of large shot at the longer ranges.

To estimate the efficiency of different sizes of shot in practice is a more complicated question than this, because the shock of a number of blows delivered at the same time is found to disable birds more suddenly than their complete perforation by one or two pellets, which may leave the wing-power still active for a considerable period. The necessary penetration is also a very important condition, as it must be sufficient to carry the pellet through the external defences of life, the feathers, flesh, &c. Penetration does not march with energy, because resistance to it increases as the square of the diameter of the pellets; and, consequently, in comparing the penetration of pellets of different sizes striking with the same velocity, their penetration may be roughly estimated to vary simply as their diameters. It will thus be seen that the penetration of No. 1 is only double that of No. 9 at those distances where they have equal velocity, although their energies are as 8 to 1. It is probable also that the resistance of flesh, &c., to the penetration of projectiles varies as a high power of the velocity. There are no

experiments to determine what this is, those hitherto made with ordnance being directed to the law of penetration in such substances as wood, brick, sand, clay, &c. The remarkable effects produced by firing rifle bullets into soft, inelastic substances, prove that the resistance increases as a high power of the velocity, the penetration diminishing when a certain limit of speed is exceeded.

The relative velocities of small shot, and of the birds and animals against which it is used, is beyond the scope of this Paper; but it will be seen that the time of flight of medium shot being $\frac{1}{7}$ th of a second for 40 yards, a very large allowance must be made in many instances to ensure striking. In the case of a driven bird crossing at that distance at a rate of 60 miles an hour (a high, but possible speed), the allowance for the motion of bird should be about 15 feet, as it will move $12\frac{1}{2}$ feet in $\frac{1}{7}$ th of a second, and the time occupied in the act of firing the gun, and the passage of the shot from breech to muzzle, must be also allowed for. It will be seen, therefore, how difficult it is to attain anything like certainty in stopping birds flying at high speeds across or overhead.

Before concluding, I would direct attention to the magnitude of the resistances developed in the air by high velocities. The resistance to a spherical shot 15 inches in diameter, moving at a rate of 2100 f. s., is **6421** lbs. A flat surface of equal diameter would experience a higher resistance. Again, the same shot started at a speed of only 1700 f. s. loses, from the resistance of the air alone, in the first 100 feet of its flight, and in less than the $\frac{6}{100}$ th part of a second, 75 *foot tons* of energy.

It appears to follow from these facts, that whenever it is sought to obtain motion by using the resistance of the air, the efforts of inventors should be directed to giving a maximum speed to their machines, rather than an extended surface. It is probable that if the problem of driving ærial machines be ever practically solved, it will be by attaining high speed in the propellers, and thus utilizing the enormous resistance which the air offers to bodies moving through it at high velocities.

V.—ON RECENT ADDITIONS TO OUR KNOWLEDGE OF THE
GOLD-BEARING ROCKS OF SOUTHERN INDIA. BY V.
BALL, M.A., F.R.S., F.G.S., Professor of Geology and Minera-
logy in the University of Dublin.

[Read, February 19, 1883.]

THREE years ago, when I read before this Society an account of the "Mode of Occurrence and Distribution of Gold in India," I pointed out that the available information as to the geology of some of the regions which were then attracting the notice of gold mining companies was very imperfect.

Recently this deficiency has to a considerable extent been removed by the publication of a Paper by Mr. R. B. Foote, of the Geological Survey of India,¹ in which he has suggested the existence of a correlation between the gold-bearing rocks now known to exist at the several localities where mining operations have commenced, and at some others where the occurrence of auriferous sands has been ascertained.

The subject, as I propose to treat it, deals especially with the geological aspect; but since so large an amount of capital—upwards of £3,000,000—has been invested in companies, it is natural that a great number of people should regard with particular interest the economic side of the question; for this reason, therefore, I think it desirable that I should make some preliminary remarks on the productiveness of Indian mines.

In the absence of detailed and thoroughly trustworthy accounts of operations at particular mines, it is necessary to be somewhat general in our statements, and yet this is a subject by no means well suited for such a method of treatment.

About a year ago I was challenged publicly at a meeting in London to state at what depth the quartz reefs would be most

¹ Notes on a Traverse across some Gold-fields of Mysore, Records of the Geological Survey of India, vol. xv., 1882, p. 191.

auriferous, and privately I have been interrogated to the same effect. The supposition that at a given depth gold would be found in comparatively great abundance is one that has received some currency from the fact that certain reefs in Australia have been worked with most profit at great depths. It is a supposition which has proved very convenient for those companies which are as yet unable to show any returns to shareholders for the large sums of money which have been expended.

Now, if we attempt to apply such an hypothesis to the region in question, we find ourselves at once landed in a maze of absurdities. The only meaning that "depth" can have in this connexion is the vertical distance downwards from the surface, which latter is, in this particular case, a most variable datum, varying in level not only by hundreds, but even by thousands of feet, since some of the reefs are believed to be traceable from high elevations on the Wynand plateau, 3000 feet above the sea, downwards to the low-lying tracts at its foot.¹ These differences in contour being mainly due to subærial denudation, it stands to reason that a depth of, say 200 fathoms, on a reef referred to the sea-level standard, is a very different thing when applied to a mine on the top of a lofty plateau to what it is when a mine at its foot is in question.

Each mine, therefore, can only be discussed on its own merits, and the outcome of all that has been done in the exploitation of gold-bearing reefs may be expressed by a truism which carries with it no hypothesis. It is simply this—that the richest part of a reef is that which, when experimentally tried, contains most gold. Similarly situated and neighbouring reefs may be found to exhibit similar phenomena; but to expect reefs situated at great distances from one another, and at varied altitudes above sea level, to exhibit any close resemblance in their characters, when mined to the deep, is a manifest absurdity.

Of the wide-spread distribution of auriferous rocks in certain parts of India there can be no doubt; and it is strange that we should not yet, after three years, be in possession of more positive evidence of their productiveness. Eighteen months ago I heard of cases of managers of mines being pressed by their London directors to push their works onwards to the deep, the natural conclusion being

¹ King, Records of the Geological Survey of India, vol. viii., 1875, p. 36.

that the reefs near the surface had not proved rich enough to work ; so that hopes for the future depended on a hypothesis as to their improvement to the deep, which had no real justification in fact. Indeed, I might add to this that in some instances these operations were, I believe, carried on where there was no true reef exposed at the surface.

I have carefully watched for consistent evidence of any of the mines proving productive to a profitable extent. There is no *à priori* reason against the capability of some of them becoming so ; but rather the contrary. Still shareholders of the companies, with scarce an exception, are now complaining that there are no results to justify the confidence which they have shown in the hopes held out to them of returns at dates now long past.

I take this opportunity of referring to a large volume which has recently been published. The author, when noticing my writings on this subject, though commending my caution, describes me as being a pessimist, and thereupon complacently incorporates into his book, without the use of inverted commas, nearly forty large pages of facts which I had most laboriously collected for my chapter on Gold in the *Economic Geology of India*.

The term pessimist when thus used must be intended to indicate a person who bases his opinion on well ascertained facts—and on them alone—and who rejects, as unsuited to his purpose, the high-flown and always sanguine views of writers whose language sometimes keeps pace with their interests. Such, at least, was my professed method ; and it may even prove that the opinion I expressed, guarded as it was, was only too favourable. I certainly believed that long ere this there would have been, in the cases of some of the companies, more tangible results than I have yet been able to hear of.

Mr. Foote has ascertained that, traversing the granitic gneissose rocks, which form the uplands of Mysore, there are several parallel zones of schistose rocks in which all the principal known gold-bearing localities are situated. Two of these zones are traceable for several hundreds of miles, and their width is in one locality, at least, eighteen miles. Although the nature of the relations

existing between these zones and the neighbouring rocks do not appear to have been as yet very fully elucidated; still, in general terms, they may be described as being formed of schists which rest in synclinal troughs upon the older granitic gneissose rocks. The schists are of various kinds—hornblendic, chloritic, hæmatitic and micaceous, the latter passing into quartzites, and in one of the zones there is a very remarkable and interesting bed consisting of an enormously thick conglomerate of pebbles and boulders of compact gneiss in a greenish-grey foliated chloritic matrix. Traversing these schists, &c., occur quartz reefs, in which traces of gold are found, and with the presence of which the existence of the auriferous deposits generally appear to be connected.

At one locality, near Honnali in Mysore, there are a great number of reefs traversing chloritic rocks. To them is traceable the source of the gold which is found distributed through the red soil, covering the neighbouring low country. Mr. Foote describes having witnessed the prospecting of some of these reefs by an experienced Californian miner, the results having been satisfactory. The quartz was found to contain gold, which was visible in grains and scales, scattered pretty freely through the mass. The “Turnbull” reef, which was the most promising of the group, could be traced, with some breaks, for a distance of nearly six miles. “The results of many washings, both of crushed quartz and of the red soil taken from many localities and various levels,” were in the majority of instances “satisfactory.” Significantly it is remarked, that the prospects in this case are certainly greater than those of other companies whose shares are, or were till lately, favourably quoted.

Regarding the Kolar field, Mr. Foote considers that the reefs found there, though small and inconspicuous at the surface, are true fissure veins or lodes. The quartz composing them is, he writes, “a bluish or greyish-black diaphanous or semi-diaphanous rock which is remarkably free from sulphides (pyrites, galena, &c.) of any kind. The gold found is very pure and of good colour. Several washings of crushed vein stuff were made in my presence at the Urigam and Kolar mines with really satisfactory results, the quantity of gold being very appreciable.” The samples, it is said, were

not picked ones, by which it is to be presumed that we are to understand that they were not exclusively from the casing walls of the reef or from the feeders.

One report which I received from this locality was, however, that the thin casing walls of the reefs and the feeders or leaders from them, alone contained gold in paying quantities, the bulk of the reefs not containing gold sufficient to pay the cost of extraction. Similar observations have been made by Mr. King with reference to some of the Wynand reefs. Where such is the case the matter narrows itself into a purely mining question, whether in following to the deep and extracting these casing walls the expense of dealing with a comparatively large proportion of practically barren rock will not exceed the produce from the paying portion. The feeders, in the majority of cases, are probably of too limited and capricious a distribution to admit of being mined to any extent.

It is, to the best of my belief, fully two years since some of the engines and stamps were set up at Kolar, so that shareholders cannot be accused of undue impatience if they now ask for results.

Regarding the geological age of these gold-bearing rocks, it seems probable that they belong to the lower transition or sub-metamorphic series of India, the representatives of which, as I showed in my previous Paper, are also auriferous in Bengal.

In lithological characters, especially in the prevalence of chloritic schists, there is a very close resemblance. Invariably I found in Bengal that chloritic schists, traversed by quartz reefs, were to be found in the vicinity of those tracts where the auriferous sands were richest. The coincidence was far too constant to have been accidental.

I cannot but believe that there are localities in India where gold, in paying quantities, exists. A failure upon the part of a number of the companies to produce profitable results would not necessarily invalidate this opinion. Some have acquired properties which are, probably, worthless, while others have a heavy burden of capital which may prove most detrimental to their prosperity; but the most competent men who have examined the properties are unanimous in asserting that some of the mines are of promise.

A large measure of success would be of enormous importance to India, as the production of gold there would tend to reduce the rate of exchange which at present causes so much loss to the public and to private purses. At the same time, to be appreciably felt the outturn should amount to several millions sterling, otherwise it would not influence the enormous transactions between India and Europe: these at present are the cause of a process of depletion which is most detrimental to the best interests of the former country, while it does no good whatever to the latter.

VI.—ON THE POSSIBILITY OF GOLD BEING FOUND IN QUANTITY IN THE CO. WICKLOW. BY GEORGE HENRY KINAHAN, M.R.I.A., &c.

[Read, February 19, 1883.]

IN a Paper read some little time since before the Society, "On the Mode of Occurrence and Winning of Gold in Ireland,"¹ the writer gives a very exhaustive account of the Wicklow Placer mines, while since then our Honorary Secretary, in his admirable report on the Economic Geology of India,² seems to suggest "that very little more gold is to be found in the Gold-mine Valley"; and the object of this Paper is to lay before the Society the general facts of the case.

From the explorations in different portions of the world, it has been learned that in connexion with a Placer mine, gold may be found—first, in the mother-rock (*reefs or veins*); second, in the higher shallow alluvium of the valley (*shallow placers*); third, in the lower deep alluvium of the valley (*deep placers*); fourth, in the alluvium of the beds of the high, now dry, supplementary streams of the ancient or primary valley (*dry gulch placers*); and fifth, in the shelves, or high level flats, on the sides of valleys (*shelf, reef or bar placers*),³ the latter being the relics or records left of the floor of the ancient primary valley—they proving that prior to the present time the gold was in the first instance deposited in a comparatively wide shallow valley; while the alluvium of the present stream is the rewashed drift of the ancient valley mixed with newer detritus. Now in modern times, in none of the valleys of the Co. Wicklow has gold been found, or even looked for, except in the first, second, and fourth cases.

¹ Gerrard A. Kinahan, Scientific Proceedings, Royal Dublin Society, vol. iii.

² Geology of India, Part iii., "Economic Geology," by V. Ball, M.A., F.G.S.

³ The term reef is, in part, confusing, as "reef mining," as used in some countries, refers to the crushing up of the quartz veins or reefs—while in other places the same term "reef" is applied to the high level flats.

The gold of this portion of Wicklow has been found sparingly, *without tin ore*, in "black sand," and more abundantly in connexion with tin ore and wolfram. On the accompanying map I have marked in red (they being copied from the maps of Gerrard A. Kinahan) the places in the immediate vicinity of the Gold-mine Valley where gold has been found, and with blue lines most of the principal open casts made in search of the "quartz-reef" or "mother-rock" of the gold. To the westward, in the Coolbawn valley, gold and tin were found in quantity north of where the letter A is marked on the map; in the S.W. branch of the Gold-mine river gold and a quantity of tin were found north-east of the place where B is marked; while in the S. branch they were found north and north-east of the letter C; it may, therefore, be naturally suggested that if a "mother-rock" exists, it ought to be found somewhere near one of these points; while, as far as can be learned from the records, no researches have been made in connexion with such an idea. Mills indeed suggested that the high ground of Ballinasillog, to the north of B, should be tried, but his suggestion was overruled by Weaver and Kirwan: there is also the high land of Knockmiller, between B and C, that has not been tried; while immediately eastward there is more untried high land, although in the valley of the townland of Mongan there are indications that strongly suggest the presence somewhere thereabouts of a mineral vein. It therefore appears to me that until after the high land in these localities has been investigated it would be rash to assert no gold reef exists.

To the westward, in the upper portion of the Tomaskela river valley, gold has been proved to exist, but never worked for. In the Coolbawn stream and its eastern tributaries all the diggings were shallow, the search being abandoned when the head of drift became twelve or fifteen feet deep. However, three miles to the N.W., near the Darragh water, where the alluvium was again shallow, the gold was worked. There is, therefore, in the Coolbawn valley three miles in length of untried deep alluvium.¹

In the valleys of the S. W. and S. branches of the Gold-mine

¹ Weaver began trials in this deep ground; but when he found the drift was deep enough to prevent the country people from working there, he abandoned them, deep works being contrary to his instruction.

river there are no workings more than thirty feet deep, while nearly all of them are less than twelve or fifteen feet; there is therefore, in this valley at the least, over a mile of untried deep ground.

In connexion with the Darragh water or Aughrim river, the gold-bearing tributaries are:—the Tomnaskela river, the Coolbawn stream, the Ow river, the Kilmacreddin stream, the Clone stream, the Ballintemple stream, and the Gold-mine river; yet the alluvium of the valley has not yet been tried, except at Ballycoog steps, where gold was proved. The distance from the inver or mouth of the Tomnaskela river to the Lower Meeting at Wood bridge is over eight miles.

Gold has been found in the sand of the Ow and in the alluvium of its tributary, the Mucklagh brook; the untried valley from the Mucklagh brook to the Darragh water valley being over six miles in length.

Only the shallow alluvium of the upper tributaries of the Macreddin stream have been worked, there being a length of over three miles of deep alluvium between them and the Darragh water.

In connexion with the Ovoca, there is gold in the gossan of the Ballymurtagh, Upper Cronebane, and Connary mines, in the river gravel at Castle Macadam, and in the alluvium of the Darragh water and its tributaries. There is, therefore, from the Ovoca mines to the sea at Arklow a length of over six miles of untried deep alluvium. So much for the untried deep and shallow placers in the neighbourhood of the Gold-mine Valley.

In connexion with the S. branch of the Gold-mine Valley, one or two “dry gulches” were worked by Weaver, who got in them “large gold.” Nowhere else does there appear to have been exploration made in search for “dry gulches.”

The relics of the more ancient valleys, that is, “shelf,” or “bar placers,” have never been looked after; yet in many places there is a possibility, if not a probability, that such golden relics might be found. Experience in America and Australia has proved that such deposits usually, although not always, occur in the shelves at the convex side of valleys, below the level of the source of the gold; and such shelves, possibly gold-producing, are very conspicuous in places along the valleys of the Ovoca, the Darragh water, and the Gold-mine river, at heights below the known points at which

the gold was found in quantity associated with tin ore and wolfram. None of them have ever as yet been explored.

There are other places in this neighbourhood, such as Ballinglen and the Tinnahela streams, in which gold has not yet been recorded or tried for, although the indications would suggest its existence; but these it is unnecessary further to refer to.

In conclusion, however, I would submit to the Society, that to me it appears rash to give an opinion on the non-existence of gold, while the miles of alluvial ground now enumerated still remain unexplored, or while no attempt has been made to explore the shelves of the valleys.

VII.—ON THE CALCITE CRYSTALS FROM THE IRON MEASURES OF THE COUNTY ANTRIM. BY PROFESSOR J. P. O'REILLY, C.E. (PLATE II.)

[Read, February 19, 1883.]

IN the very interesting Paper read before the Natural Science section of the Royal Dublin Society, April 11th, 1881, by Mr. Philip Argall, on the "Tertiary Iron Ore Measures of Glenariff Valley, Co. Antrim,"¹ he makes frequent mention of the "aragonite crystals" which accompany the ores and are found in geodes or vugs of the roof of the ore bed, or in cells of the amygdaloidal dolerite along with zeolites, as also at other points of the deposit in fine acicular crystals. He remarks, p. 158: "Hence a display of crystals (aragonite) on the roof is regarded by some as a sign of poverty; similarly as a display of spar crystals in a standing vein indicates poverty of mineral matter in the percolating fluids when the run was being filled." At page 161 he says, "when approaching a dyke, cracks in the pavement are frequently filled with acicular crystals of aragonite."

Mr. Argall very kindly procured for me the linings of a couple of fine geodes, and in the accompanying letter explained by a sketch the position of the vugs or cavities relative to the ore bed in which the crystals are found. Subsequently, in October last, Professor Hull handed me for the Museum collection of the Royal College of Science some specimens of acicular crystals from the same contact found at Cusheadal, Co. Antrim. I had previously been engaged in examining the crystals of the vugs forwarded me by Mr. Argall, and from the densities obtained had reason to consider these crystals as being really calcspars. A further examination of the acicular crystals presented by Professor Hull lead me to the same conclusion in their regard, and I now beg leave to submit the results of this examination from the points of view of density, crystalline forms, cleavage, and hardness.

¹ Proceedings, vol. iii. (new series) part iv., p. 151.

The density of the acicular crystals presented by Professor Hull was found 2.71.

That of part of a honey-coloured crystal presented by the same 2.71.

The density of calcspar crystals is given at 2.6 to 2.8.

And for the purest crystals 2.72.

Whereas that of similarly pure aragonite crystals varies from 2.9 to 3.00.

It may, therefore, be concluded that from this character alone the crystals in question are calcspars. The further examination of the crystalline forms, cleavage, and hardness, still further confirms this conclusion. The crystals are scratched by aragonite, and the cleavage is very distinctly rhombohedral, and in no way that of aragonite. The crystalline forms are sufficiently distinct in the small acicular crystals to allow of measurement, and are clearly referable to the rhombohedral forms of calcspar. Thus the acicular crystals show on the sides the zigzag striations characteristic of certain scalenohedral forms and the angles measured on the long, short, and middle edges, give sufficiently approximatively the values corresponding to the scalenohedral form $R12$.

Long edge, calculated angle, $125^{\circ} 47'$, found $125^{\circ} 30'$.

Short edge, „ „ $114^{\circ} 50'$, „ $114^{\circ} 51'$.

Middle edge, „ „ $167^{\circ} 35'$, „ —

These crystals are terminated by the forms

$4R$, terminal edge, $65^{\circ} 50'$,

$-2R$, „ „ calculated angle, $78^{\circ} 51'$, found $78^{\circ} 00'$,

and R .

The honey-coloured partial crystal from Cushendall presented by Professor Hull shows the forms

$R12 - 2R$, and cleavage terminal faces of R .

The crystals occurring in the geodes of the iron ore bed present scalenohedral forms oscillating in a remarkable manner, and in the central zone of each face a band, or red stripe strongly marked, and representing the rhombohedral form $-2R$. The examination of several of the crystals shows that on either side of this band, itself somewhat rough, there is an oscillation of scalenohedral

forms, marked by ridges and furrows running nearly parallel to the basal section, and giving rise to a rounded face. These oscillating forms represent the scalenohedrons $-2R^2$ and $-5R^{\frac{7}{5}}$.

$-2R^2$	{	Long edge,	calculated, $153^\circ 16'$,	found, $153^\circ 57'$
		Short edge,	„ $92^\circ 9'$,	„ $93^\circ 10'$
		Middle edge,	„ $135^\circ 19'$,	„ $135^\circ 25'$
$-5R^{\frac{7}{5}}$	{	Long edge,	„ $164^\circ 59'$,	found, $165^\circ 24'$
		Short edge,	„ $76^\circ 54'$,	„ $75^\circ 58'$
		Middle edge,	„ $132^\circ 01'$,	„ $134^\circ 30'$

The roughness of the faces, and the rounded faces of the middle edges rendered closer approximation difficult. The oscillation of these forms gives to the surface of the crystal a feathered appearance, the feathering proceeding out symmetrically on either side from the red stripe representing the face $-2R$.

In other vugs occurs a combination of forms somewhat different. Thus, there is found a central pyramid of which the faces present the roughness of a ground glass plate with cleavage planes traversing them at regular intervals. This form represents the pyramid $\frac{4}{3}R^2$:

Calculated polar edge, $135^\circ 51\frac{1}{2}'$, found, $135^\circ 57'$.

On the alternate polar edges appear in process of formation, and in different stages of that process, the faces of the scalenohedron $-R^{\frac{5}{3}}$:

Long edge,	calculated, $161^\circ 53'$,	found, 161° .
Short edge,	„ $101^\circ 55'$,	„ 101° .

This last form is rarely complete, and its faces rarely cover the whole of the underlying pyramid, and in the same manner as in the case of the previously described crystals, leave a space or band along the middles of the alternate pyramidical faces, but without any red stripe.

The conditions having led to the deposition of the red mineral matter (peroxyde of iron apparently), present interest in so far as they might lead to an estimate of the temperature of the solution from which the crystals were formed. The only record existing as to actual experiment in this respect is that of Sénarmont (*An. de Ph. and Ch.*, t. xxx. p. 129), who transformed the hydrated peroxyde of iron into anhydrous peroxyde by heating it in a

closed vessel at 180° C. in presence of water, or in a saturated solution of chloride of magnesium or chloride of calcium. The product obtained was red, amorphous, and resembling the common variety of natural sesquioxide of iron. Why the central band of the crystal should alone present this oxide is not so easily explained, unless by the hypothesis that crystals of either carbonate of iron or iron pyrites were deposited on this surface, and then subsequently transformed into peroxide. That certain faces of crystals induce, or facilitate such deposits is well known; and that the state of the surface of the face is an essential factor in the phenomenon is also well known: the primary cause is, however, less clearly explainable.

That no precise conclusions could be drawn from the presence either of aragonite or calcspar as regards the temperature of the solution from which the crystals were deposited would appear from the synthetical experiments of G. Rose, which tend to prove that both calcite and aragonite may be formed in warm solutions. The conclusions of a review of all the synthetical experiments made up to the present relative to these two minerals are thus stated by Messieurs Fouqué and Levy in their remarkable work, "*Synthèse des minéraux et des roches*" (1882), p. 203:—"In the greater number of cases, natural calcite and aragonite appear to result from the decomposition of solutions of bicarbonate of lime more or less concentrated, and more or less warm. The crystals formed affect the rhombohedral, or rhombic forms according to the temperature at which the crystallization takes place."

In this case the presence of the red band of sesquioxide of iron would tend to prove that the solution, at one particular stage, was warm, and as this was a final stage, the probability is that the calcite crystals were formed from warm solutions of bicarbonate of lime.

VIII.—NOTES OF TRANSIT OF VENUS, AS SEEN AT THE
CRAWFORD OBSERVATORY, QUEEN'S COLLEGE,
CORK, 6TH DEC., 1882. BY [PROFESSOR ENGLAND.
Communicated by Howard Grubb, F.R.S.A.

[Read, December 18, 1882.]

THE time was taken by chronometer set to Greenwich time, and checked by the signal gun at 1 o'clock of the day of the transit, the proper allowance being made for the time occupied in the transmission of the report. The observations were made with the 8-inch refractor, furnished with polarizing eye-piece. The field of view was by this contracted to about 5' diameter.

The telescope was directed to the sun at about 1^h 30^m, and adjusted so that the E. limb of the sun bisected the field of view, and the planet should appear near the middle. A few minutes before the calculated time of contact my attention was altogether directed to the dark part of the field, hoping to see Venus before contact. In this respect I think the limited field was an advantage; but no appearance whatever was observed until after 2^h 2^m, when a slight *notch* was observed on the sun's limb very near the centre of the field. It took a few seconds before I could be absolutely certain of this, on account of the apparent undulatory motion on the sun's edge. The observation may therefore be considered of *no* value as regards time of contact. The planet gradually advanced on the sun—the disc beautifully defined—until it had somewhat more than half entered on the sun's disc, when the part without the sun became visible, the eastern edge being distinctly luminous, very similar to what is seen in the moon a few days after new moon, except, of course, the planet was much darker than the moon, no difference being apparent between the part on the sun's disc and that without it, except near the eastern edge. The cusps now gradually approached, and at 2^h 21^m 51^s I signalled to my assistant to register the time. It was not, however, until twenty seconds after, viz. 2^h 22^m 11^s, that I felt satisfied of contact, and the limb of the sun was only clearly visible outside the planet at

2^h 22^m 16^s. As I have stated, much uncertainty necessarily results from the flickering motion of the cusps.

During the whole time the planet was visible it appeared perfectly circular ; no deformity whatever, as 'black drop,' 'pear shape,' &c. When once fairly on the disc of the sun I did not pay much attention to any subsequent phenomena. Our Observatory being situated within the College grounds, and being chiefly intended for educational purposes, I was anxious to have our students, as far as possible, see the transit. For this purpose the image of the sun was thrown on a sheet of white paper by the siderostatic telescope, the image being about 6 inches in diameter : the image of the planet was very distinct, and over one hundred individuals were thus enabled satisfactorily to see the transit.

I should have stated that observations here made by the siderostatic telescope, one before the junction of the cusps at 2^h 21^m 27^s, the other after the light of the sun was well seen at the eastern side, 2^h 22^m 20^s.

IX.—OBSERVATION OF THE TRANSIT OF VENUS, 1882, DECEMBER 6, MADE AT THE ARMAGH OBSERVATORY.
BY J. L. E. DREYER, PH. D.

[Read, December 18, 1882.]

ON the morning of the 6th of December the sky was quite overcast, and snow fell for about an hour between nine and ten o'clock. About noon it began to clear, and with the exception of a few light clouds passing now and then, the sky continued perfectly clear until about three o'clock, when the sun was again hidden by clouds.

For observing the transit I employed the 15-inch reflector, which is equatorially mounted in the east tower of the Armagh Observatory. The instrument can be used either in the Cassegrain or in the Newtonian form: I preferred the latter, and had a plane unsilvered mirror substituted for the usual metallic flat mirror. The negative eye-piece (power 140) was furnished by Mr. Grubb, with a wedge of neutral-tinted glass, which permitted the observer to diminish the intensity of the solar heat so as to make it pleasant to the eye without rendering the mottled appearance of the photosphere indistinct. The eye-piece was carefully focussed on the solar limb, and on several faculæ, and with the diminished aperture of seven inches both the limb and the mottled surface of the sun were extremely well seen.

I tried to observe the external contact of Venus with an aperture of eleven inches, but the definition was far from good, the limb 'boiling' violently. At 1^h 36^m 14^s, local mean time, I was certain that the outer contact *had* taken place. Having exchanged the diaphragm used with one of seven inches aperture, the definition was much improved, and before the second, or internal contact occurred, it became almost all that could be desired. At 1^h 49^m 31^s the whole circumference of Venus was visible, that part of the planet which had not yet entered on the sun being projected on the bright sky adjoining the solar limb. At 1^h 54^m 49^s·6 Venus was completely on the sun; but a faint, narrow shade-like band

appeared at this moment, filling the interval between the cusps. This shade was steadily visible until $1^h 55^m 24^s.5$, when it broke, and gave place to a very thin bright line which separated the two limbs. At $1^h 55^m 51^s$ I noted "interval between limbs very conspicuous."

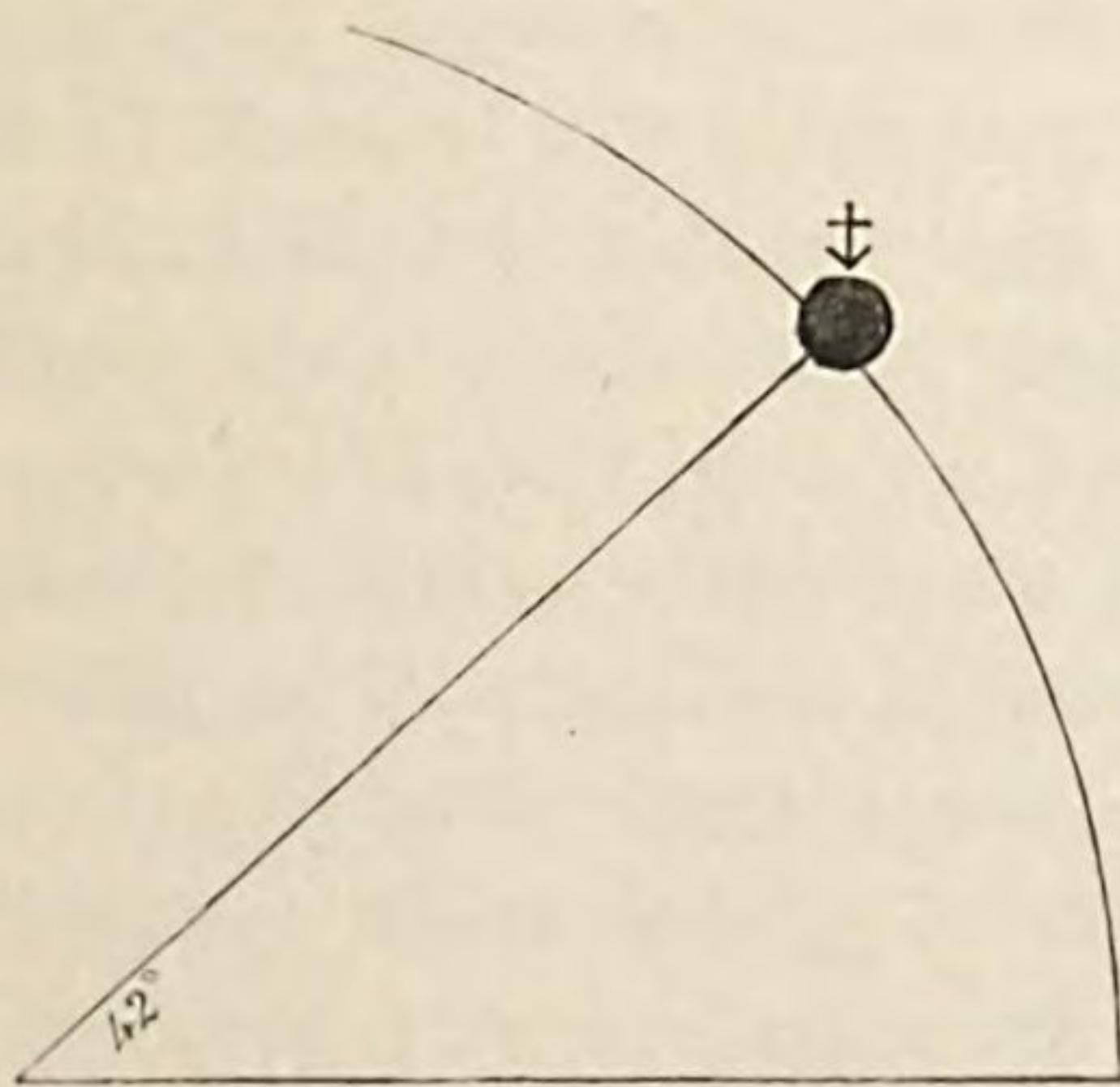
On referring the same evening to the volume of British Observations of the Transit of 1874, the observation of ingress by Commander Wharton, at Rodriguez, was found to correspond in most particulars with mine, and his Fig. 3, on Plate xiv., represents the "shade," as seen by me just before breaking.

The transit was also observed by the Rev. Charles Faris, Assistant Astronomer, with the $7\frac{1}{2}$ -feet achromatic finder (object-glass 3.8 inches) attached to the reflector. As the pier hid us from one another, and we took care to record what we saw without speaking, our observations may be regarded as perfectly independent. Mr. Faris did not see any disturbance of the limb at internal contact, but saw the cusps meeting at $1^h 55^m 10^s.6$. He had observed external contact at $1^h 35^m 35^s$.

X.—NOTES ON THE TRANSIT OF VENUS, AS OBSERVED AT
STREETE, CO. WESTMEATH. BY W. E. WILSON, F.R.S.A.

[Read, December 18, 1882.]

THE 6th was cloudless throughout. The error of the Observatory mean time clock was got by a transit of the sun at noon. The 24-inch reflector was stopped down to 12 inches, and a polarizing eye-piece used. The 4-inch finder was also used with a power of 75. The first contact was observed at $1^{\text{h}} 31^{\text{m}} 54^{\text{s}}$ Streete mean time. I was not quite sure of the exact position-angle that contact would take place at, so that I am sure the above time is a few seconds late. The time I calculated for first contact was $1^{\text{h}} 31^{\text{m}} 14^{\text{s}}$ S. M. T. At $1^{\text{h}} 38^{\text{m}}$ the entire disc of Venus could be seen against the corona. The planet seemed much darker than the corona, and was surrounded by a thin ring of silvery light. This ring was much brighter at the place marked in the following diagram by $\dagger$. I suppose it was caused by a bank of clouds in the planet's atmosphere.



Internal contact occurred at $1^{\text{h}} 52^{\text{m}} 14^{\text{s}}$ S. M. T., and is, I believe, very close to the calculated time. There was no appearance of "black drop." The two cusps of light were almost quite sharp, and gradually closed up until they touched. As soon as Venus was well on the disc I mounted the spectroscope, and made a careful search for any absorption lines in the planet's atmosphere.

Nothing of any certainty was observed. I thought some of the lines near D were thickened a little at their base, but I would not place much reliance on the observation. The sun by this time was getting very low, and the image of the planet was unsteady. If the atmosphere of Venus is about the same depth as the earth, it will easily be seen that it would be an exceedingly thin ring round the planet, and by placing the planet over half the slit it would be most difficult to see the short absorption lines. My telescope being a Cassagranian, and giving a large image of the planet, would have a better chance than the Newtonian or Refractor. During the forenoon the sun was observed on the chance of seeing a transit of a satellite of Venus with a negative result.

XI—ON MODES OF DEALING WITH ECHOES IN ROOMS. BY
 GEORGE JOHNSTONE STONEY, D. Sc., F.R.S., a Vice-
 President of the Society.

[Read, December 18, 1882.]

IN almost all large apartments echoes are troublesome. If the room is used for music, echoes destroy the purity of the sound; if for oratory, they render the utterance of the speaker indistinct. Any mode of mitigating these bad effects is useful, and if it goes the length of practically annulling them, it will be of signal service. This induces me to lay before this section of the Society the result of some experiments on the subject which I had occasion to make several months ago.

Echoes in rooms arise from sound reaching the ear, not only directly but also after reflection, and sometimes after more than one reflection, from the ceiling, the four walls, and the floor. If a large audience be present, the floor ceases to act as a reflecting surface, and there will remain the walls and ceiling. In all cases, the effect which results largely depends on the circumstance that the sound-waves, especially those of low pitch, are of considerable size compared with the extent of the wall, so that reflection is not of that simple and definite kind which occurs when light is reflected from a mirror, but partakes largely of the diffuse character which we see when light falls on surfaces which are not polished. The reflection of sound-waves is intermediate between the two ways in which light is reflected, and tends more towards true reflection in the case of the short waves which belong to sounds of high pitch, while the reflection becomes more and more an irregular scattering of sound from the reflecting surface, in the case of long waves of low pitch. This difference of effect in the cases of long and short waves is well known to the mathematicians who have studied the interference of waves, and it is unnecessary to give the proof here as it may be found in all text-books on the subject. But it is well to point out that it contributes largely to that marked indistinctness which echo in a room gives to the utterance of an orator. The

fundamental sounds of a man's voice which constitute the chief body of the sound consist of long waves, eight or twelve feet in length, and are returned to us in varying directions from almost all the reflecting surfaces from which the sound can be scattered back. They thus constitute a loud echo of these low tones of the voice. On the other hand, the much more acute sounds upon which articulation depends, which make the difference between one vowel-sound and another, or between one consonant and another, consist of waves so short that they are reflected from a wall almost quite in accordance with the law of reflection, and only reach such ears as are in the definite line in which they are reflected. But few of the audience can be so placed; these hear, indeed, the proper sounds, but disordered as regards time, so that it is often difficult for them to follow the speaker: and the rest of the audience are worse off; they hear an abundant sound, but cannot easily catch any words. This latter effect is apt to be felt in a large room with bad echoes, even where the orator speaks so slowly that his syllables reach his audience almost separately. In such cases, the lighter and shriller elements of articulation are drowned in the fundamental tone of the speaker, reinforced by reverberation from the ceiling and walls; and the mischief only increases if the speaker endeavours to meet it by speaking very loud. All that he can successfully do is to hiss out his consonant sounds with unnatural strength, while taking care not to allow the fundamental sound of his voice to pass beyond a moderate strength.

In contrast to the case of an audience occupying the whole floor stands that of a single listener placed in a position selected because it is the focus of reflections from suitably curved surfaces. In this case the higher tones are reflected with such precision to the focus in which the listener stands that they reach him with almost no abatement, while the bulk of the sound, the fundamental tone of the voice, is enfeebled because much of it has been scattered by the reflecting surfaces in other directions than towards the focus. Hence, in such situations, the articulation of the speaker seems preternaturally distinct, as all persons who have visited such a whispering gallery as that in St. Paul's must have observed.

These remarks will serve to direct attention to the conditions of the problem. The way to deal with it falls naturally under two heads, according as we have to make the best we can of an existing

room without altering it, or are at liberty to prepare the room specially.

In the first case, it is obvious that by placing the speaker in one corner of the room, we eliminate the direct echo of the two walls which meet at that corner. This is already a great gain, especially if one of the other walls of the room is broken into spaces by windows. In that event there will remain little direct echo except from the ceiling, and the farther end wall: meaning by *direct* echo the sound which has only once been reflected. By this simple contrivance it has been found that if the speaker takes proper care with his enunciation, all the audience can be made to hear sufficiently distinctly, except those occupying a few definite situations, which can be easily ascertained by experiment, and might with advantage be left without seats.

Still further mitigation may be effected by placing the speaker in that corner of the room where the two worst, that is, the most uninterrupted, walls meet, and by bringing a canopy of sufficient size as close over his head as convenient. In the experiments which have been made this canopy was made of cotton cloth stretched on a horizontal frame six feet square, and was brought within a few inches of the head of the speaker. It should be of larger size if placed farther from him, and will be sufficient for our purpose if it prevents his seeing either the ceiling or the upper parts of the walls opposite to him. The anticipated effect is as follows:—Distinguishing the sound of the speaker's voice into the fundamental note on which he speaks and the overtones which give articulate-ness to the sound, it was expected that the overtones, consisting of waves so short that they cannot readily bend round obstacles, would reach the audience with nearly the full force given to them by the speaker, and that but little of this constituent of the sound would bend enough to reach the ceiling and the walls. On the other hand, the fundamental note would more readily spread upwards, and would, therefore, produce some, although a reduced, echo. This slight echo along with the part of the fundamental note received directly from the speaker's mouth, ought apparently to be heard as a fundamental note of the proper strength to be rendered articulate by the overtones received directly from the speaker, and therefore received by the ear at the proper times to make the utterance distinct. In the experiments which have been made it

was not found practicable to distinguish all the elements which theory seems to indicate, but of the marked improvement effected by introducing the canopy there can be no doubt.

This concluded the first part of the inquiry. The second was directed towards ascertaining whether it is possible to construct a room without echo, or to alter an existing room in such a way as will free it from echo. The experiment I proposed to make was to hang paper draperies on the walls and from the ceiling; but before I incurred the considerable trouble and expense of doing this I accidentally found that one of the large apartments of the Exhibition Palace, in Earlsfort-terrace, had its walls papered over a lining of canvas, the canvas being a short distance (from one-eighth to a quarter of an inch) in front of the framework over which it was stretched. These are precisely the conditions that I had desired; and, very fortunately, the ceiling of this room is so nearly covered by skylights that there is but little echo from it. On trying the experiment in this room, with the floor occupied by an audience, I found no appreciable echo that could be referred to the walls. There was indeed a very short echo, very unlike the prolonged echo of an ordinary room of the same shape and size, sounding like the letter R very roughly pronounced, with a faint burst, which lasted not, I think, more than the eighth or tenth of a second. This I believe to have been due to the partitions which separate the numerous skylights of which I have spoken.

From this experiment I believe it may be safely inferred, that a concert hall or room for public oratory may be effectually freed from echo by the extremely simple expedient of lining its walls and ceiling with canvas, kept at a slight distance away from the walls. The ceiling must be included in this treatment, if it is to be effectual, as a large part of the echo usually comes from it. The canvas may be papered, or distempered, or painted, so that there need not even be any change in the room visible to the eye.

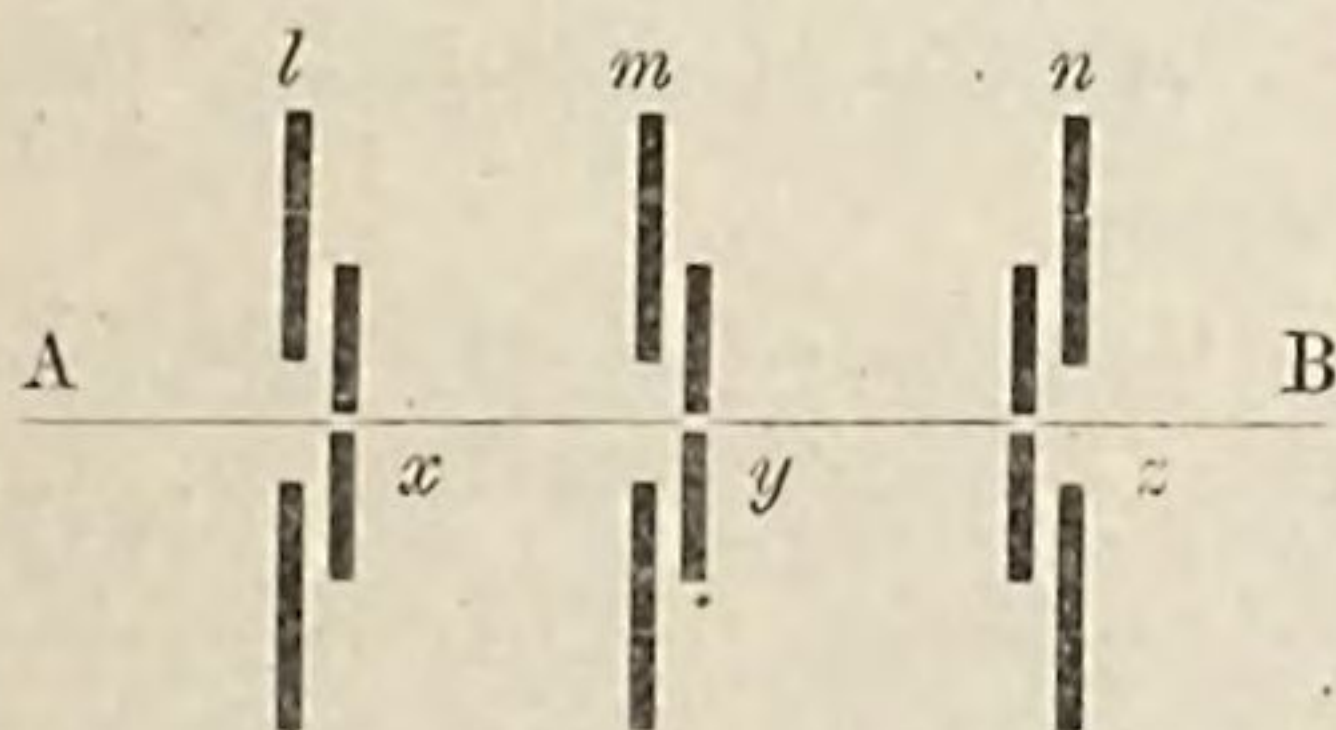
XII.—ON DR. EDDY'S HYPOTHESIS THAT RADIANT HEAT IS AN EXCEPTION TO THE SECOND LAW OF THERMODYNAMICS. BY GEORGE F. FITZGERALD, M.A., F.T.C.D.

[Read, December 18, 1882.]

IN the Scientific Proceedings of the Ohio Mechanics' Institute for July, 1882, and at the meeting of the American Association for the Advancement of Science in Montreal, Dr. Eddy proposed an exceedingly ingenious experiment, by which he expected that it would be possible to get radiant heat to pass from a cooler to a hotter body. I had the pleasure of hearing his Paper at Montreal, and though I then saw no flaw in his reasoning, I pointed out to him that he had only taken two of the bodies concerned into consideration, yet I dared not express a decided opinion on the matter without further consideration. The further consideration has resulted in my thinking that the reasoning is not valid, as I hope to be able to point out.

I shall take what seems to me an experiment somewhat simpler in theory, though one that would be harder to carry out in practice, than Dr. Eddy's.

Suppose that two regions A and B, separated by three parallel screens l , m , and n , having apertures in them x , y , z , capable of



being opened and closed from the centre, so as to make everything perfectly symmetrical round the line AB perpendicular to the screens. Now, if x be opened for a very short time, a certain quantity of radiant energy will escape out of A into the region between l and m ; and if y be opened when this heat reaches m it can certainly be let on into the region mn ; and if z be similarly opened

when it reaches it, this radiant heat will get into B. While z was open, however, some heat left B; but as Dr. Eddy observes, y may be closed so as not to let this even get through the screen m , and it can be all returned into B by reflection through z or some other aperture. So far I entirely agree with Dr. Eddy, and so far it seems as if the result had been to transfer heat from A to B without B's losing any heat by having it transferred to A. As I warned Dr. Eddy when I heard his Paper, there are, however, other bodies and regions to be considered besides A and B. There are more than two bodies considered: there is the region of the screens. Consider what happens when the heat that escaped out of B into the mn region tries to get back into B. Some door must be opened to let it pass, and, while it is passing in, an, at least, equal amount of heat will be passing out of B into the mn region, so that you can never really get the heat that has once left B back into B again. This is true whether you adopt doors over fixed apertures such as I have supposed, or moving apertures such as Dr. Eddy proposed. What really takes place is this: a certain quantity of heat escapes out of A and reaches B, and a not less quantity of heat leaves B and is kept entangled in the region of the screens, and it is only possible to let the heat pass from A to B by means of this third region. Hence this only really comes to the same thing as letting A radiate some of its heat into the screen region while B is kept closely shut up. Now be it observed that Dr. Eddy practically postulates that this screen region is at least colder than A—in fact he assumes it to be perfectly cold, *i. e.* to contain no radiant heat except what is admitted from A and B, so that it is by no means contrary to the theory of exchanges that A might cool by radiating into this region.

This seems to me to be a perfectly satisfactory explanation of what would take place, though it, for the present, dispels the vision of an immortal universe. This experiment of Dr. Eddy's, however, seems to call attention to the fact that a region of motionless ether must be considered as practically a cold body capable of absorbing radiations.

XIII.—ON EQUAL TEMPERAMENT, AND ON THE CAUSE OF
THE EFFECT UPON PIANO MUSIC PRODUCED BY
THE KEY IN WHICH IT IS SET. BY G. JOHNSTONE
STONE, D. Sc., F.R.S., a Vice-President of the Society.

[Read, March 19, 1883.]

PERHAPS, of all the canons of Art, that one is the most important which declares that correctness in Art is not identical with accuracy in Mathematics. It would be no just criticism of the outline of a drawing to say that inaccuracies could be detected with a microscope. Correctness in a work of Art has been fully attained when the deviations have been kept below what can be noticed by the human beings who are to be impressed by that work of Art. Hence in Art a latitude within certain narrow bounds is not only allowable, but commendable. Even when no other advantage is gained by it, the tolerance of it, at all events, preserves the artist from misapplying his powers.

But there are cases where new artistic effects of importance can be obtained by deviations, and then they deserve to be commended on other ground, and in a higher degree. Thus, in the pictorial Art, that part of the appearance of standing out in relief which is given to natural objects by what astronomers call parallax is absent. All the objects in the painting are necessarily in one plane, and we cannot judge of their distances by our binocular vision, or by slightly moving our heads, as we habitually do judge of the distances of natural objects. Hence the artist is only able to suggest these distances by the sizes of the objects in his picture, and by the colours, lights, and shades he throws over them—the parallaxic element is necessarily absent.

If the artist augments the effect produced by colours, lights, and shades beyond what exists in natural objects, he can in part supply the place of the absent element; and, if he avails himself of this resource with skill and moderation, the augmentation falls within such narrow limits, that it is not felt by the beholder as a

deviation from nature, and is to be appreciated as artistic excellence: if it transcend those limits it is perceived to be exaggeration, and offends.

The principles which underlie these remarks apply with singular force to music. Judging from the literature on the subject, it may be said that people of an arithmetical turn of mind are sometimes apt to forget that artistic correctness has been fully attained when the outstanding errors have been reduced below what the cultivated ear can perceive, and both the arithmeticians and those who are devoted to the simpler forms of melody and harmony are apt to overlook what one would think is very obvious—that some sacrifice of one artistic effect may be welcomed when it procures for us new artistic effects of sufficient value, and especially where the new field of effects is of such vast range as it is in instrumental music, and the effects themselves of a kind to be keenly relished by those who have the good fortune to be gifted with a comprehensive appreciation of harmony.

Of this kind are the advantages acquired by tuning pianos on the system of equal temperament. In this method of tuning, each octave is divided into twelve equal semitones. This method of tempering plainly puts it within the power of the composer to indulge in absolutely unlimited transition from key to key, for it provides the same intervals in all the keys.

It was for a piano tuned in this way that Sebastian Bach composed the unrivalled preludes and fugues of his “*Wohltemperirte Clavier*,” and many of these, as well as a great deal of the best modern music, would be impossible without the unrestricted power of modulation which is thus provided. This immense advantage ought to be candidly admitted by those who recommend other methods of tempering.

On the other hand, there are effects and exquisite effects, which cannot be attained with instruments tuned in this way, which will only come forth when suitable music is executed in the natural scale, *i. e.* the scale indicated by the mathematical theory, or in a scale very closely approximating to it. This natural scale does not in its fifths differ sensibly from the scale of equal temperament, but its thirds and sixths are perceptibly smoother; and it has two supertonics to be used respectively according as this note is associated with dominant or subdominant harmony. I would wish

to urge that it is a great pity that, when glees are sung without accompaniment, more care is not taken to bring out the exquisite effects which enchant the hearer when the music which is adapted to it is rendered in this scale.

One obstacle to this is, that people become partisans. The Tonic-solfaists, who have widely advocated the natural scale, are sometimes not content without also disparaging tempered instruments, forgetting that many of the best instrumental effects have no existence with the natural scale. And on the other hand, some lovers of the richest harmonised effects speak very unappreciatively of the praiseworthy efforts of the Tonic-solfaists to extend the use of the natural scale.

The truth is, that each in its own place is the best, and we deprive ourselves of much of the legitimate delight of the most delightful of all arts by limiting our choice to one only—to either the natural scale, or the scale of equal temperament.

I need not pursue these general considerations farther, for my immediate object is of limited scope. What I desire particularly to invite attention to is to one collateral advantage among those which render the system of equal tempering of importance to us, viz., that it provides us on the piano with twelve keys which differ essentially in the artistic effects which they can produce.

Nothing about Art is more astonishing than the extreme subtilty and delicacy of the causes which weave webs of the strongest influence about our minds. They are very difficult to make out, and in many instances have defied every effort that has been made to bring them to light. It is my aim on the present occasion to endeavour to obtain some insight into one of these—to try to trace out what minute shades of difference produce that remarkable difference of artistic effect which we perceive in the various keys *on the piano*—to endeavour to find out why the key of A is so well adapted to joyous, bright, and sparkling effects, while its close neighbour, the key of A $\flat$, is gentle, soft, and liquid—why D and E are brighter than E $\flat$, and so on.

This great difference does not depend in any considerable degree on pitch nor on the tempering. In fact, as Helmholtz points out, if two pianos are tuned one a semitone lower than the other, these keys will preserve their distinctive characteristics on both. Even though the key of A on the one piano is made to consist of

identically the same tones as the key of A $\flat$ on the other, their artistic effects will be wholly different. Nor does this variety of effect depend on tempering, for it is present on pianos carefully tuned on the system of equal temperament, where all the semitones are alike, and it continues to be equally perceived by the ear on pianos tuned with all the little deviations from this system of temperament which are common in practice. We are thus driven to attribute it to some inherent difference of effect of the black notes and the white notes on the piano. Helmholtz suggested this as the direction in which the explanation must be sought, and by making that suggestion he furnished the key to the solution, which, however, he does not himself pursue farther.

Each note of the piano is a complex tone. In addition to the fundamental tone, it contains its octave, its twelfth, and its double octave, but these harmonics are present in proportions which differ somewhat according to the strength with which the note is struck. Hence the quality of the note is subject to a slight variation according as it is struck firmly or gently. In the first case the tone is of a richer quality; in the second case it is softer, *i.e.* it contains a less proportion of the higher harmonics. Now upon the pianos upon which I have experimented there was a *very* slight, but still perceptible, difference in *intensity* with its accompanying difference in quality, when the regulated impact of a mechanical apparatus was alternately delivered upon a white and on an adjoining black note. This difference appears to me to be somewhat greater when the two notes are struck successively by the same finger with what is judged to be the same force, and as nearly as possible in the same way. And the difference becomes conspicuous when the black note is struck from the more horizontal and extended position which the fingers that reach the black notes necessarily assume in the ordinary course of playing. The black notes will then give out a tone which is sensibly gentler, less rich, and softer, *when the performer seems to himself to be exerting the same force on them and on the white notes.* So far the effect is to be attributed chiefly to the positions of the fingers, and in small degree to the different sizes and proportions of the levers in the piano which terminate in the black and white notes respectively. Helmholtz suggests that the narrowness of the black notes may have some influence, but I have not been able to refer any part of the observed effect to this

source. Their being separate from one another, with open spaces between, does however facilitate that horizontal position of the fingers which seems to produce a softening effect, unconsciously to the performer.

On pianos which have been some time in use, the difference in quality between the black and white notes is *very much* augmented by the white notes having been more used than the black, and the hammers having, from this cause, become harder. On such pianos the greater part of the observed effect is probably due to this hardening of the hammers and consequent reinforcement of the upper harmonics; but it cannot be any part of the cause on new pianos; and, accordingly, on new pianos the variety of artistic effects in the different keys is less distinct. Assuming that the keys of A, A $\flat$, B $\flat$, C, D, E, E $\flat$, F, and G, or their relative minors, are equally played upon a piano—and the great preponderance of music is in one of these keys—the white keys will, on the average, be used twice as much as the black; and when the softness of a new piano is beginning to be lost, the deterioration will affect the white keys more than the black. It is easy to assure oneself that from this cause the black notes of pianos which have been much played on are, over a great part of the keyboard, sensibly softer than the white.

We have next to inquire how a softer quality of tone in the black notes, whether it arise from the fingering or from their having been less used, can produce the difference of artistic effect in the different keys which is observed. And here what occurs on the violin comes to our aid. The notes G, D, A will, whenever played, be reinforced by sympathetic vibrations in the open strings. And it is found that on the violin the brightest keys are those in which the tonic, dominant or even subdominant, chance to fall on these notes. Hence the effect of joyous brightness is due to a slight difference of this kind between these notes of the scale and the rest.

Before proceeding farther, it is well to state the principal facts to be accounted for as they are presented to us in piano music. The bright effect of sharp keys appears to my ear to culminate in A major with three sharps, and to be present in a very marked degree in D with two sharps, and in E with five. The soft effect of flat keys seems to me to be at its best in A $\flat$ major with four

POSITIONS OF THE MAJOR CHORDS IN THE KEYS OF A AND A $\flat$.

In the key of A the notes of the major chords fall .	on white notes.	on black notes.	on white notes.
Tonic chord ,	do	mi	so
Dominant chord,	so	ti	re
Sub-dominant chord,	fa	la	do
In the key of A $\flat$, they fall,	on black notes.	on white notes.	on black notes.

In the minor chords there is also a contrast, though less uniform in these two keys.*

All these circumstances betoken that the musical effect of the two keys should be different, and it only remains to inquire why the difference of effect which we have established tends towards brightness in the one key and towards softness in the other.

This is undoubtedly in part, because the third or middle note of a major chord† is the source of sweetness in the chord, while the end notes are the sources of its strength. In each of the major chords of the key of A $\flat$, this source of sweetness is slightly reinforced as compared with the other notes of the chord; while in the key of A, the middle note falls below the others in intensity and richness.

We may also connect it with the mysterious, but undoubtedly real, effects which the several notes of a scale produce on the mind when once the scale has become firmly established in the ear. These, when occurring in slow music, may be stated to be (following nearly the description of them given by the Solfaists) :—

* The contrast of the minor chords attains uniformity in the keys of E and E $\flat$.

† In minor chords, the middle note appears to be the source of the greater piquancy which we perceive in minor chords; and in the key of A, and still more in the key of E, this element is relatively stronger than in the keys of A $\flat$ and E $\flat$.

In Major Keys.	Name of Note.	Prevailing artistic character in slow Music.	In Minor Keys.
	la		The tonic.
	ti		The supertonic.
The tonic, . . .	do	The firm note,	The mediant.
The supertonic, . .	re	The hopeful note, . . .	The sub-dominant.
The mediant, . . .	mi	The gentle note, . . .	The dominant.
The sub-dominant,	fa	The solemn note, . . .	The sub-mediante.
The dominant, . . .	so	The strong note, . . .	
	si	The submissive note, . .	The leading note.
The sub-mediante, .	la	The sorrowful note, . .	
The leading note, .	ti	The sensitive note, . . .	

No single word will convey the variety of impressions made upon the mind by each note, but the impressions made by each form a natural group, and an attempt is made in the above Table to indicate one of the central members of each group. It however requires considerable modification when the music moves rapidly.

Now observe that in the key of A $\flat$ it is the firm note, the hopeful note, the solemn note, and the strong note, which are softened by falling on black keys; while on the other hand the gentle note, the sorrowful note, and the sensitive note, are relatively emphasized; and this, taken in conjunction with what has been stated above, will abundantly account for the gentle liquid effect which can be produced in so striking a manner by this key.

The key of A stands in contrast to this. Here the gentle, sorrowful, and sensitive elements of the music are placed in the background, while prominence is given to the firm, hopeful, solemn, and strong elements. Hence A major, and its allies D and E, are eminently the keys for powerful, rousing, and joyous effects on the piano.

It would be tedious to go through the details of applying this method to all the major keys, and it is less necessary as it is easy for the reader to satisfy himself that this method of treatment will give a tolerably good account of the peculiar effect of each upon our emotions.

In treating minor keys it will have to be remembered that la,

the sorrowful note, is now the tonic (see Table on p. 65); after which come in order ti, do, re, mi, and fa, exciting nearly the same sentiments in our minds as the notes of the same names in the major mode. So is absent, and in its place we have si, the leading note of the new tonic, the impression on the mind produced by which may be described as prevailingly submissive. It will be anticipated from these data that each minor key should produce a mental effect closely allied to that of its *relative* major, and this quite accords with experience.

On the other hand, the general effect of a *tonic* minor is usually broadly contrasted with that of its major, in consequence of its being three removes off, and the effect which attaches intrinsically to the new key, on account of the additional flats in it, in some cases contributes sensibly to the peculiar effect which modulation into the tonic minor produces, although the main part of the effect of a tonic minor is, of course, relative and not intrinsic. The augmentation of the effect produced in this way is most felt where the intrinsic effect of the new key is in consonance with the natural effects produced by the minor mode. To see this, compare a modulation from A major to A minor, in which case there is little or none of the augmenting effect here spoken of, with a modulation from F major to F minor, in which it is conspicuously present.

It will be sufficient to give one application of these principles to minor keys, and as in dealing with major keys I endeavoured to take the most conspicuous example, I will here take one that is less prominent. In Beethoven's universally known sonata with the Funeral March (Op. 26), a marvellous effect, unusually stately and self-contained as well as solemn, is produced by the opening phrases of the March. To this effect the key which Beethoven selected has contributed. It is not only the tonic minor of the preceding movement, but it is A $\flat$ minor, the key in which do, fa, and si are on white notes, and therefore emphasized in comparison with the other notes, unconsciously to the performer. These are the firm, solemn, and submissive notes, and their being so emphasized appears to contribute to the peculiar effect of the opening passages of the piece. The attitude of firmness thus established is made to grow within the mind of the hearer by that form of insistent composition of which Beethoven was such a master,

and is supported by the keys through which the music is next successively led. The effect is increased by first passing from A $\flat$ minor to its relative major, viz. C $\flat$, which differs from the minor by omitting the submissive note. After this it passes into the tonic minor of C $\flat$, viz. B minor, a powerful key, and thence into its relative major, the key of D, thus reaching by steps of ever-increasing strength that which is perhaps the most powerful of all the keys on the piano. When this effect has been thus made to culminate, the prolonged repetition of one of the chords of minor thirds, and the sudden drop upon the original key through its fa—the most desolate of all notes—produces on the mind of the hearer a mixed feeling of pain, settled gloom, and determination, befitting the subject of the piece. Then follow other effects which we need not follow. These modulations would be impossible except on an instrument tuned on the system of equal temperament, or one closely approximating to it.

Finally, and to this I would particularly request attention, a complete corroboration of the foregoing method of treatment can be had by transposing very simple slow movements into the key of C major or A minor, as the case may be, taking care to finger so as to soften the notes which in the original key fell upon black notes. In this way an artificial imitation of that key may fairly well be produced. The experiment succeeds best when the key imitated is one with flats, probably because the effect of such keys is easily brought out in very slow movements. For instance, F minor can be thus imitated. This observation appears to supply a satisfactory confirmation of the views which I have ventured to submit to the Society.

The effects of different keys which have been the subject of investigation in this Paper are, of course, peculiar to the piano. They are either not met with or are quite different on the organ, and in an orchestra. Any effects of the kind observable on the organ are probably to be attributed to the tempering, and have no such connexion with black and white notes as on the piano; and in an orchestra any special effect of a particular key which the ear observes must be the complicated resultant of the peculiarities of many instruments, unless when (as it probably sometimes is) it is simply due to an association established in the memory of the hearer by the familiar experience of the effect of that key on the piano.

XIV.—A GEOLOGIST'S CONTRIBUTION TO THE HISTORY OF ANCIENT INDIA, BEING THE PRESIDENTIAL ADDRESS TO THE ROYAL GEOLOGICAL SOCIETY OF IRELAND. BY PROFESSOR V. BALL, M.A., F.R.S., F.G.S.

[Read, March 19, 1883.]

It has devolved upon me, somewhat out of the ordinary course, to deliver to you an address at the commencement of my term of office. The ill health of the late Professor Leith Adams precluded his addressing you last year, and the duty was undertaken by the Rev. Dr. Haughton, whose long connexion with this Society rendered it particularly fitting that he, who for many years has been its principal stay and supporter, should be our President on the occasion of the celebration of our fiftieth anniversary.

Having completed one year of office he has resigned, and proposed my election as his successor. This proposition having been adopted by the Council, and ratified by the Society at large, I find myself placed in this honourable position at a period when my service to the Society has been but of short duration, and my connexion with the progress of geological research in Ireland of still less mature age.

I have to thank you very sincerely for the high honour you have conferred upon me. It is a source of extreme gratification to me to find myself enrolled on the now long list of Presidents of the Royal Geological Society of Ireland. Since that first meeting of the Society, held in the Provost's house in November, 1831, there have been periods of great prosperity, as necessarily there must have been, since so many men of distinction who have held office were active in the furthering of the objects expressly laid down at the time of incorporation.¹

¹ At a meeting held at the Provost's house November 29, 1831, it was resolved:—"That the gentlemen present do form a society for the purpose of investigating the mineral structure of the earth, and more particularly of Ireland, to be called the Geological Society of Dublin, and that to promote this investigation the Society shall hold periodical meetings, collect books, maps, specimens, and other objects relating to geology and mineralogy, arrange the collection in a museum according to the most approved classifications, publish papers and essays, and contribute in every other possible manner to the progress of geological science."—*Extract from Minute Book.*

Our Minutes, which have been carefully kept for the half century, and the attendance-books, which are still extant, contain a most interesting record of the past. We can learn from them that the subjects discussed at the evening meetings served to attract and bring together, at one time or another, all those who have felt an interest in the progress of geological research in Ireland. There were many, too, who were perhaps more directly identified with other branches of science; still, by their presence at the meetings, they conferred upon the Society a status and influence which were widely felt at the time.

Looking down that roll of past Presidents, there may be seen the names of many men whose accomplished work has secured for them a world-wide reputation, and among them, perhaps, I may be permitted as a personal matter to refer to those to whose teaching and encouragement I owe it, that twenty years ago I adopted the career of a professional geologist. Drs. Haughton and Apjohn and Professor Jukes were my instructors here, and by Dr. Oldham I was inducted into the duties of an Indian field geologist. It is natural, therefore, that I should feel honoured at being appointed as their successor, and it will be readily understood that I experience a very special gratification at being appointed to succeed the instructor of my earliest youth—my father, who exactly thirty years ago, or in 1853, delivered the Presidential address.

It would be wrong were I to conceal the fact that we are not now in a prosperous condition. The Society has seen better days, but let us hope not its best. Just at present, from whatever cause, possibly from superior attractions afforded by other branches of science, active interest in geology appears to exist only among a limited number.

We stand in need of more members who will not only, by their subscriptions, place the Society in an improved position as regards its means for meeting its requirements, but who will, by contributing Papers, enable us to produce a journal which, from its variety and originality, will continue to prove acceptable and useful here in Ireland, and will serve to increase the Society's reputation in distant lands.

The machinery exists, and is now in active operation, for exchanging our publications with those of the principal learned societies all over the world, and we have the testimony of our

correspondents that our journal is acceptable in exchange for the publications of other societies, of which many possess a high intrinsic value.

But those who have to provide the material for the journal are not unmindful that it falls short, not only of being what it ought to be, but even of what it might easily be, if all geologists in Ireland would give their aid.

We want a larger income to enable us to provide fitting illustrations. Many Geological Papers require, in order to be intelligible, more or less costly illustrations, and writers of such Papers would, doubtless, be more willing than they are at present to use our journal as their medium of publication, were they assured that such illustrations could be given with their Papers. To a certain extent our present association with the Royal Dublin Society enables us to produce the journal at a less cost than would be the case were we working single-handed; but in our straitened circumstances we have hitherto been enabled to avail ourselves of this aid as regards illustrations to but a very limited extent.

Those of our members who contribute with most regularity to the journal—and the list of them is not a long one—give the Society not only their best and most important Papers, for which they might obtain a wider publication elsewhere, but they also give Papers of minor importance, the professed object of which is to provide the Society with material for its meetings.

This is, perhaps, a not altogether healthy state of things; a longer list of contributors, and fewer contributions from the same individuals, would indicate a wider basis of support. In purely provincial societies, whose existence is due to the exertions of a few energetic individuals, such is to be expected; but it behoves us all to do our utmost to place and keep this Metropolitan Society in a higher rank than is ordinarily attained by a merely provincial society. The Royal Geological Society of Ireland is entitled by its past history and reputation to the support of everyone interested in the geology of Ireland in particular, and of residents in Ireland who are interested in general geology, all of whom we call upon to contribute their aid in the directions above pointed out.

No one has realized the Society's state of affairs more fully than our outgoing President; he naturally feels anxiety for its future, while its existing condition ever presents itself to him in

his capacity as Treasurer. As a means of quickening the public interest in our operations, and of aiding in the development of Ireland's industrial resources, he has proposed a scheme to the Council, the outlines of which it is now my duty to announce to you.

Dr. Haughton considers that the past history of the attempts which have been made to develop the mineral resources of Ireland affords a safe guide as to the particular directions in which that development may be most profitably prosecuted. He accepts it as demonstrated by experience, which has been purchased at great cost, that the metallic ores occurring in this country—absence of suitable fuel, &c., being taken into consideration—are, with one notable exception, not of great present value. He further considers it to be the case that the prospect of profitable exploitation on an extended scale afforded by the coal-fields of Ireland is not very encouraging.

There are, however, on the other hand, mineral resources as to the abundance and value of which there is no doubt whatever, and to these he proposes that certain members of the Society should direct their particular attention, with the view of drawing up a series of reports or monographs which will, it is hoped, prove of practical commercial value.

The scheme has so far advanced that the duty of preparing these reports has been allotted and undertaken as follows:—

- | | |
|---------------------------------|---------------------|
| I. Paving Setts: | Dr. Haughton. |
| II. Antrim Iron Ores: | Professor Hull. |
| III. Slates: | Professor O'Reilly. |
| IV. Ornamental Building Stones: | Professor V. Ball. |
| V. Cements: | } Not yet allotted. |
| VI. Pottery Clays: | |

The co-operation of all whose positions and opportunities may enable them to give aid in the way of statistics or suggestions in reference to these subjects is earnestly solicited, and all aid so afforded will be duly and thankfully acknowledged.

We hope to show by these reports that, while on occasions we may occupy ourselves with questions of a more or less abstract nature, we are not unmindful of what we conceive to be our duty

in respect to the application of scientific treatment to practical subjects.

In support of the statement made above as to the commercial value of some of the productions which have been enumerated, reference need only be made to the large export trade which is done in Antrim iron ores; to the granite setts and ornamental granites which are exported from Newry, the former having been sent as far as Chicago, and the latter to Bucharest, and it may be added as being, perhaps, still more noteworthy, to Glasgow. The roofing slates of Ireland are not as yet by any means so largely employed as they deserve. I say this while fully conscious that they sometimes have defects which militate against their universal employment.

Every resident in this city is aware that there are here in Dublin a number of chemical works engaged in the preparation of manures, bleaching powders, acids, &c. Although I know it is not the case in all, still at one of these works I found recently that no one of the substances of mineral origin which were used in these manufactures was the product of Irish soil.

As might be expected, all the metal-work of the machinery and the lead of the acid vats had been imported. The phosphates were from South Carolina and Cambridgeshire. The pyrites from Spain, after burning it, is reshipped to Swansea, where it is treated in the wet way to extract a small percentage of copper present in the ore. The manganese and the salt were also imported, and so were the large stone slabs used in the construction of the acid vats. Nay, more, the very limestone used in the manufacture of bleaching-powder comes from England, although Ireland is so especially a limestone country; and, in the Co. Antrim, possesses chalk of exceptional purity, which is, to some extent, exported from Belfast to England, to return, perchance, as bleaching-powder, for the use of the linen works.

Nearer at hand to us, at Skerries, I am informed, that a limestone of good quality is obtained; yet neither it nor the Templemore limestone, also well suited to the purpose, are used at the particular works I refer to, though they are at others.

The, as yet, unallotted subjects upon which we hope hereafter to publish reports, namely, the cements and the pottery clays, are certainly not of least importance. The materials are known to

exist, and probably will be found in some quarters where they have not as yet been discovered. There seems to be every prospect of cements being more extensively used in the future than they have been in the past, and it is for the benefit of our buildings, no less than for that of the industry itself, that a cheap local supply should become abundant.

As for pottery clays, Belleek affords ample testimony of the presence of suitable materials, and the capabilities of native talent. Why that particular industry has not yet proved commercially successful I cannot say—it has certainly deserved to be so.

I shall not further encroach now upon these subjects, which belong to the forthcoming reports, and will, no doubt, be discussed in them. Nor shall I enter upon any discussion as to the political questions which influence, in a superlative degree, the development of this country's industrial resources.

No fact is more generally acknowledged than that capital is sensitive. Each possessor of it illustrates this truth by the manner in which he makes his investments. He may make mistakes, and he may send his capital to countries of which he knows nothing whatever, but he does not ordinarily invest his property in a country while he knows it to be in a condition of unrest.

Circumstances, it is to be hoped, will bring about a condition of rest and renewed confidence here, and, in the meantime, we purpose preparing information on the above subjects, which will serve to indicate directions in which capital, when available, may be invested with the best prospect of future profit.

A question has informally arisen among some of the Members in reference to the circumstances under which we at present hold our meetings, whether we should not be in a better position as regards the accession of new and active interest of old Members, if we had a more distinct local habitation, with our own library and so forth. But this question was, to the best of my belief, fully decided some years ago by circumstances which, while the Society regretted, it could not control. There are, probably, few younger Members of the Society than myself here present, and so I will not say more on a subject of which most of you know more than I do. But this may be said as regards the present, we don't know how far our orbit of revolution as an independent body is from its completion. Fifty-one and a-half years ago we started on our career

as a satellite of the Royal Irish Academy; we are now in close proximity with another body, but whether we shall merge into it, or on the conclusion of our period be re-absorbed by our original parent, time only can determine. Having entered, however, on the second half-century of our existence as an independent body, let us hesitate before we take any step which may hasten our reaching a condition of *nirvana*, as our doing so would have one effect, among others—it would deprive posterity of the supreme gratification of celebrating our centenary.

As on an occasion like the present some latitude is permissible in the selection of a topic, I have chosen the following as the special subject of my address:—

A GEOLOGIST'S CONTRIBUTION TO THE HISTORY OF ANCIENT INDIA,

Being an attempt to identify the sources whence the mineral productions were derived, which are mentioned by the Historians of India from the earliest times to the close of the eighteenth century.

THE subject of this Paper first attracted my attention in connexion with the preparation of the accounts of the diamonds and gold of India, read before this Society in the year 1880. Subsequently, when collecting materials for my volume on the Economic Geology, I found that there were many obscure historical notices upon which our modern knowledge of the geology of that country was capable of throwing much light. Although some of the translators and critics of the ancient writings, which afford the principal part of my data, have sought to illustrate their authors' meanings by references to the results acquired by the systematic examination of the mineral resources of India in recent times, still there is often a considerable amount of vagueness and inaccuracy in these references, and, so far as I can ascertain, there has not as yet been published a comparative and categorical analysis of the numerous allusions to the mineral resources of India, which are to be found in writings belonging to the period extending from the earliest times of which any records are extant up to the close of the eighteenth century.

Much has been done in the matter, however, by Mr. King, in his several masterly works on precious stones; but the mode of treatment here adopted differs from his in being primarily based on our present knowledge of the mineral resources of India. Had all the data now available on that subject been before him there would have been little new for discussion in such a Paper as this.

The facilities which I have enjoyed for consulting authorities, both in Calcutta and here in Dublin, in the rich treasury of rare volumes in the library of Trinity College, have enabled me to present a much longer list of writers than would have been possible had the field of research been limited to but one of these sources.

Two methods of employing the collected facts were open to me—either to arrange them under subjects or under authors' names: the latter, as it presents a general view of the development and increase of knowledge, has been adopted. It is not without the manifest objection that the same subject crops up again and again in a disjointed manner; but if the facts had been arranged under the heading of subjects, the communication would have taken the form of a treatise on Economic Geology of India, which would scarcely be a suitable one for such an occasion as the present.

The earliest traders in Indian commodities, of whose proceedings we have any record, were the Egyptians. According to Le Normant,¹ the bas-reliefs of the temple of Deir-el-Bahari at Thebes represent the conquest of the land of Pun under Hatasu. "In the abundant booty, loading the vessels of Pharaoh for conveyance to the land of Egpyt, appear a great many Indian animals and products not indigenous to the soil of Yemen—elephants' teeth, gold, precious stones, sandal-wood, and monkeys."

Again,² "The labours of M. de Bohlem (*Das Alte. Indien*, vol. i. p. 42), confirming those of Heeren, and in their turn confirmed by those of Lassen (*Ind. Alt.* ii. p. 580), have established the existence of a maritime commerce between India and Arabia from the very earliest period of the annals of humanity." The

¹ *Hist. Anc. de L'Orient*—English edition, vol. ii. p. 299.

² *l. c.* p. 301.

principal commodities imported from India were gold, tin, precious stones, ivory, &c.

In the Mosaic period (1491–1450, B.C.), too, precious stones, which were to a great extent a specialty of India and the neighbouring countries, appear to have been well known, and were already highly valued. It is probable that some of the stones in the breastplate of the high priest may have come from the far East. The emerald, however, if then known, was probably derived from a mine in Egypt, to which reference will be made hereafter. At the same time there are grounds for believing that the word so rendered (Exod. xxviii. 18; Ezek. xxviii. 13) may not be correctly translated.

The next traders in Indian products were the Phœnicians, who for a time carried on their commerce with the ports of Aden, Cana, Haran, Yemen, and Muza, to which the commodities of India were brought for exchange by Arabian, and possibly Indian and Cingalese, ships.

Somewhere about 1015 B.C., Solomon joined Hiram, King of Tyre, in a nautical and commercial venture of a more ambitious nature than had previously been attempted, "For the king had at sea a navy of Tharshish with the navy of Hiram: once in three years came the navy of Tharshish, bringing gold and silver, ivory, apes, and peacocks."¹

These ships were the first which had ever doubled the southern parts of Arabia and then sailed straight for India. The first port in that country of which we have any mention is Ophir. The vessels were built of timber from Judea, at Elath and Erziongeber, and they were manned by Phœnicians. They were called "ships of Tharshish," because they were of the same form and build as those which had previously been employed in the trade to Tharshish, situated, as is now generally known, in the south of Spain.

It is needless, perhaps, to discuss here the many views which have been put forward as to the identity of Ophir. Lassen² says it was on the site of Abhira, on the western coast, adjoining the province of Guzerat. Others locate it in Ceylon; but General

¹ 1. Kings, i. 22; also see ix. 28., &c.

² Indisch. Alter., vol. ii. pp. 584–592.

Cunningham's researches place it also in the Gulf of Cambay. The name Ophir, or Sophir, he identifies with *Sauvira*, a name derived from that of the ber-tree (*Zizyphus jujuba*), which is plentiful in that region.¹

Since gold, silver, ivory, apes, and peacocks are productions of India—and the Hebrew name for the last is derived from *tukki*, an Indian word—there is internal evidence that Ophir was situated in that country. It is not likely to have been in the more Eastern, Burmese, or Malayan countries, where, it must be admitted, the same commodities might have been obtained.²

Passing the notices of precious stones to be found in the biblical books written during the course of the next five centuries, we find that Herodotus (fifth century B.C.) gives us some insight into the nature and extent of certain Indian mineral productions. Babylon obtained precious stones and dogs (probably Thibetan mastiffs) from India.³

In the enumeration of the nations and tribes which paid tribute to the Persian monarch, Darius, the Indians alone, we are told, paid in gold, all the others paying in silver. The amount of this gold was 360 Eubœic talents = £1,290,000. Herodotus pointedly, moreover, speaks of India as being "rich in gold";⁴ and he relates the famous and widespread fable of the gold-digging ants, the origin of which has been fully ascertained, as I have already described in these pages.⁵ I shall only add now that the "horns of the gold-digging ants," referred to by Pliny and others, were, probably, simply samples of the ordinary pickaxes used by the miners. In Ladakh, and, probably, also in Thibet, these implements are made of the horns of wild sheep, mounted on handles of wood.

¹ Anc. Geog. of India, pp. 496-7; and 560-62.

² Mr. Eastwick estimates that the gold which reached Solomon by way of the Red Sea amounted to 3,330,000 lbs. in weight, or 160 millions sterling. In his Paper entitled, "Gold in India," it may be added, he is inclined to locate Ophir in the Malabar country, in the neighbourhood of the gold-bearing regions of Southern India.

³ Herodotus, i., 192.

⁴ *l. c.* iii. 106.

⁵ These Proceedings for 1880. The fable has been shown by Sir Henry Rawlinson and Dr. Schiern to have originated in the peculiar customs of the Thibetan gold miners, which would appear to be the same at present as they were in the time of Herodotus. The name "Ant" gold was possibly first given to the fragments of gold dust brought from Thibet on account of their shape and size.

The portion of India conquered by Darius was probably situated chiefly to the north-west of the Indus. The Indus itself, as well as some of its tributaries, is known to be auriferous.

Many commentators on the above and other references by subsequent authors to the existence of gold (and silver), as indigenous products of India, object that mines of these metals are or were not known to exist in India. Thus Lassen says: "If the ancients speak of abundant gold in India, it is either only a false amplification of the early and true account of Northern India, the country of the Dards, between Kashmir and the Upper Indus, or a false conclusion, from the fact that the Indians used much gold for ornaments and other purposes." Heeren, like Lassen, alludes doubtfully to Pliny's statement (*vide postea*) as to the existence of abundant gold and silver mines in the country of the Nareæ: he attributes the quantity of gold which must have been in Ancient India to commerce with other gold-producing countries, namely, Thibet and Burmah. He even suggests¹ that African gold found its way to India in early as well as it is known to have done in later times.

Our most recent knowledge of India, however, affords evidence that the amount of gold derived from indigenous sources must have been very considerable before the alluvial deposits were exhausted of their gold throughout wide regions.

When it is remembered that about 80 per cent. of the gold raised throughout the world is from alluvial washings, and when this fact is considered in connexion with the reflection that wide tracts in Australia and America, formerly richly productive, are now deserted, being covered with exhausted tailings, it can be conceived how these regions in India, and there are very many of them, which are known to be auriferous, may, in the lapse of time, after yielding large supplies of gold, have become too exhausted to be of much present consideration.

More than this, however: recent explorations have confirmed the fact, often previously asserted, that in Southern India there are indications of extended mining operations having been carried on there.

Evidence exists of the most conclusive kind of large quantities

¹ Asiatic Nations, vol. iii. pp. 408-9.

of gold having been amassed by Indian monarchs, who accepted a revenue in gold dust only, from certain sections of their subjects, who were consequently compelled to spend several months of every year washing for it in the rivers.

The already-quoted facts taken from the pages of the Bible and Herodotus must be accepted as evidence that gold was an export from India, and that to so large an extent, that the suggestion that it was first imported may be safely rejected. A large amount, very probably, reached Northern India in the course of trade from Thibet; but it is incredible that the vast stores which, as will be shown on a future page, were in the possession of the princes of Southern India about 600 years ago, was, to any considerable extent, derived from extraneous sources.

Much uncertainty exists as to the date of the famous Indian epic known as the Ramayana. By Wilson, however, it is supposed to have been written about 300 B.C.; but it refers to a time probably contemporaneous with Solomon. It represents India as abounding at that early period in wealth, which we cannot but conclude was mainly of indigenous origin. In the description of the capital town of Ajodhya, as quoted by Heeren,¹ we are told "it was filled with merchants and artificers of all kinds; gold, precious stones, and jewels were there found in abundance; everyone wore costly garments, bracelets, and necklaces." Again, "The present made to *Sita* consisted of a whole measure of gold pieces and a vast quantity of the same precious metal in ingots: golden chariots, golden trappings for elephants and horses, and golden bells are also noticed as articles of luxury and magnificence."

The *Indika*, by Ktesias, the Knidan (398 B.C.) was the first regular Greek treatise on India. The fragments of it which have been preserved by Photios and other writers have recently been brought together and carefully annotated by Mr. M'Crindle, to whose work I am indebted for the following extracts bearing upon our subject. Ktesias's knowledge of India was all derived at second-hand from persons he came in contact with at the Persian Court, where he resided under Darius and his successor, Artaxerxes Memnon.

¹ Asiatic Nations, vol. III., chap. ii. p. 355.

Ktesias informs us that there is a lake in the country of the Pygmies upon the surface of which oil is produced. The Pygmies are described as being covered over with long hair. A tribe corresponding to this description has been reported to exist in Upper Burmah, and there also are the only largely productive petroleum deposits, which, moreover, we know to have been worked since the earliest times.¹ Silver also was and is found in this region.

This report, however, it should be clearly understood, requires very distinct confirmation before it can be accepted. It is probably merely a fable; but the existence of sources of rock-oil and silver in Upper Burmah is noteworthy, no other region being known to produce both, though silver is found in many localities in India, and rock-oil in Assam and the Punjab.

The elektron or amber of Ktesias, a product of trees, was certainly *shellac*, and the insects found with it, which yielded a red dye, were lac insects. As, therefore, this amber does not properly belong to our subject, I shall say no more about it at present.

Gold, we are told, was only obtained on certain "high-towering mountains" inhabited by the griffins—a race of four-footed birds, about as large as wolves, having legs and claws like those of the lion, and covered all over the body with black feathers, except only on the breast, where they are red. Now, if we omit the word "birds" in the above, and for "feathers" read "hair," there is no difficulty in recognising the griffins as the Thibetan mastiffs, which are powerful, hairy, often black-and-tan-coloured dogs, specimens of which, by the way, appear to have been taken to the Persian Court as examples of the gold-digging ants, which were first described by Herodotus.² We may, I think, therefore, justly conclude that the locality referred to was situated in Thibet.

Gold was also said to be obtained from a spring, being drawn from it in earthen pitchers in which it congealed. This story is obviously founded on the casting of ingots; but I cannot see that

¹ Economic Geology of India, p. 138.

² Herodotus (i. 192) tells us, as pointed out by Le Normant, that India supplied Babylon with "precious stones and large dogs; and so great was the passion for the latter, that Tritantæchmes, Satrap of Babylon under the Achæmians, had set apart four cities or large villages, exempted from all other taxes, on condition of maintaining his dogs."—Manual of the Ancient History of the East, vol. i. p. 496.

Lassen's view, that it shows that the Indians knew how to extract gold from *ores*, follows, since it may merely refer to the melting of alluvial gold dust.

Silver is said to occur also in the above-mentioned country of the Pygmies, upon which Lassen remarks that silver is only known to occur in Ajmir. It has, however, a much wider distribution, as I have shown in my "Economic Geology"; but the only region in which it is regularly produced at present is Upper Burmah.¹

Iron is said to be found in the same spring or fountain as the gold; and Ktesias had two swords, made of Indian iron, given to him respectively by the King of Persia and his mother. This iron consisted, I believe, of ingots of *wootz* or cast-steel, from which Damascus blades have been made since time immemorial.² The power of iron to ward off thunderstorms, which is referred to by Ktesias, suggests rather an early knowledge of the use of lightning conductors than of the properties of the magnet, which is the explanation offered by Baehr.

The *Pantarba* is a kind of stone which, when thrown into the water, had the power of drawing together other stones of various colours to the number of 77. It has been suggested by Count Von Veltheim that this was some kind of opal, which, on being put into water, exhibited a rich play of colours. Upon this I can offer no opinion: no more probable supposition suggests itself to my mind.

The sardine stone, the onyx, and other seal stones, are said to be found in certain high mountains. There is no further indication of locality. Possibly, Oujein, in Malwa, or some of the other places where mines of Chalcedonic minerals occur, was intended.

Evidence of various kinds exists that in the time of the Indian monarch, Asoka, about 300 B.C., the mineral resources of India were well known and were largely availed of. Stone architecture on a magnificent scale, which is still extant, bears testimony to the skill of the Buddhist stone-masons of a still earlier period. The elaborate carvings on some of these prove the excellence of the tools which were employed; probably they were made of Indian steel or *wootz*. The famous Asoka monoliths of a later date, from 35 to

¹ Economic Geology, p. 234.

² The name *wootz*, according to Lassen, Indisch. Alt. (i. p. 239), is derived from the Sanskrit *vag'ra*, from two words signifying diamond and thunderbolt.

40 feet long, and about as many tons in weight, are, in their way too, remarkable, though not exhibiting such ornate designs.

In B.C. 307, according to the *Mahawanso*,¹ the King of Ceylon (or Lanka), Dewananpiatisso, was installed, and shortly afterwards he sent an embassy to Asoka at Palibothra, the presents consisting of sapphires, lapis-lazuli, rubies, and eight varieties of pearls, which, we are told, rose miraculously from the earth and sea respectively on the auspicious occasion. Asoka's return-gift consisted of golden and other ornaments, and as an especial rarity, "costly hand-towels, which to the last moment they are used (are cleansed by being passed through the fire) without being washed."

Now, with reference to the above, I venture to think that the translator has made a mistake as regards lapis-lazuli. It has never been known to be a product of Ceylon. The word possibly means either the asteria (or star sapphire), or another blue mineral called iolite (or dichroite), both of which occur in Ceylon. In this connexion it may be interesting to note that, in some excavations made recently on the supposed site of Asoka's throne,² there were obtained sapphires and emeralds, mostly broken into splinters, two pebbles of iolite, some beads of lapis-lazuli, coral, &c., and some imitation emeralds, made of glass. Lapis-lazuli, therefore, was possibly known in Asoka's time, but probably it did not come from Ceylon, but from the mines in Badakshan, to be mentioned hereafter.

The hand-towels were most likely made of woven asbestos, a substance which has long been known to occur in Kabul,³ and may very possibly have reached India from thence.

The work by Megasthenes (302 B.C.), entitled *τα Ἰνδικά*, no longer exists, except in fragments, which have been quoted by subsequent writers. These have recently been brought together by Mr. M'Crindle from the pages of Strabo, Pliny, Arrian, Diodorus, &c. It is probable that these fragments represent only a small portion of the whole work; but so far as they go, since the individual quotations by each of the authors are checked by those of the others, we are justified in the belief that the

¹ A History of Ceylon for Twenty-four Centuries, from B.C. 543: translated by Turnour, p. 70.

² *Vide* Proc. As. Society, Bengal; May, 1881, p. 89.

³ Economic Geology of India, p. 519.

general facts related are as they were originally stated by Megasthenes.

The first statement bearing on our subject is taken from Diodorus¹:—

“And while the soil (of India) bears on its surface all kinds of fruits which are known to cultivation, it has also under ground numerous veins of all sorts of metals, for it contains much gold and silver, and copper and iron in no small quantity, and even tin and other metals, which are employed in making articles of use and ornament, as well as the implements and accoutrements of war.”

Upon this I shall only here remark that the item of greatest interest is the tin. Even in Homeric times reference to this metal as coming from India is to be found in conjunction with the mention of *elephas* or ivory. The Greek name for it, *kassiteros*, is moreover said to be derived from the Sanskrit, *kastira*. That India produced tin in sufficient quantities for exportation is, I believe, most improbable. The tin which she did export probably came to the Indian ports from the Malayan countries or Tenasserim.

The fable of the gold-digging ants, already alluded to as having been related by Herodotus, is quoted by Strabo and Arrian from Megasthenes. Arrian further also refers to the account by Nearchos,² who says that “he had not himself seen a specimen of the sort of ant which other writers declare to exist in India, though he had seen many skins of them which had been brought into the Makedonian camp.”³ But Megasthenes avers that the tradition about the ants is strictly true—that they are gold-diggers, not for the sake of the gold itself, but because by instinct they burrow holes in the earth to lie in, just as the tiny ants of our own country dig little holes for themselves; only those in India being larger than foxes, make their burrows proportionately larger. But the ground is impregnated with gold, and the Indians thence obtain their gold. Now, Megasthenes writes what he had heard from hearsay, and as I have no more exact information to give, I willingly dismiss the subject of the ant.”

¹ Ancient India, p. 31.

² M'Crindle's Arrian, p. 217.

³ These I believe to have been skins of the Thibetan mastiffs (or griffins), which, I understand, are still brought to India for sale.

Pliny, in his list of the Indian Races, which is believed to have been mostly borrowed from Megasthenes, says:—"Next follow the Nareæ, enclosed by the loftiest of Indian mountains, Capitalia. The inhabitants on the other side of this mountain work extensive mines of gold and silver." Capitalia may certainly be identified with Mount Abu; and although the highest authorities are divided as to the identity of the Nareæ, the mention of mines of gold and silver compels me to believe that the Nairs of Malabar were intended, as in Malabar and the neighbouring regions are situated not only the ancient gold mines which have attracted so much notice of late years, but there are also enormous ancient mines in the districts of Kadapah and Karnul from whence argentiferous galena appears to have been extracted, and from this ore silver was, very probably, obtained.¹

In another passage in this list of Pliny we find the following statement:—"Gold is very abundant among the Dardæ and silver among the Setæ." On this Mr. M'Crindle remarks that the Setæ are the Sata or Sataka of Sanskrit geography, which locates them in the neighbourhood of the Daradas. I was inclined to believe that the country of the Setæ may have been the Wazir-i-rupi, or silver country of the Wazirs, *i.e.* Kulu, where argentiferous galenas undoubtedly do occur.

Colonel Yule identifies them, however, with the Sanskrit *Sekas*, and he places them on the Bannas, about Jhajpur, south-east from Ajmir. There are extensive ancient mines from which galena was obtained near the Taragarh hill in Ajmir; but, so far as I can ascertain, there is no record of their having produced silver. Galena, known to contain silver, appears to have been mined for at Jodawas in Alwar, and at Jawar or Zavar in Udepur, but this latter locality was chiefly remarkable, indeed unique in India, for producing zinc.²

Further on, in Pliny's enumeration above alluded to, we meet the following passage:—"Beyond the mouth of the Indus are

¹ *Vide* Economic Geology of India, p. 232.

² Todd (Rajasthan, p. 12, 504), has described this as being a tin mine, an error which has misled Lassen (*Indisch. Alt.*, vol. i. p. 239), who states that the large production from this mine may account for the fact that the Indian name of tin, already alluded to on a previous page, was at so early a period spread throughout the western world.

Chrysæ and Argyræ, rich, as I believe, in metals. For I cannot readily believe, what is asserted by some writers, that their soil is impregnated with gold and silver. At a distance of twenty miles from these lies Crocala." This last, according to Mr. M'Crindle, is identified with Karkalla, the district which includes Karachi; but Colonel Yule identifies the former two localities with Burma and Arakan, as will be mentioned below in connexion with Ptolomey's reference to the same subject.

About the year 30 B.C. Dionysius Perigetes, in his "*Oikoumenes Perithesis*," gives a rough indication of the position of the region from whence the diamonds which at that time found their way to Europe were derived.¹ The *adamas*, he states, together with beryl, green jasper, topaz, and amethyst, were found in the river beds of the country lying to the east of Mount Parapamissus (*i.e.* the Hindu Kush) and Ariana. Although some doubt may be felt in this instance as to the true meaning of the term *adamas*, its applicability to the diamond, when used by Manilius a few years later, is indisputable. This latter author flourished during the Augustan age (B.C. 31 to A.D. 14), but the exact date of his poem is not known.

PLINY, A.D. 77.—In his *Historia Naturalis*, the industrious compiler Pliny has given an extraordinary amount of information regarding precious stones and metals, a large proportion of them being of Indian origin.

Reference has already been made to those passages which appear to have been derived from the older authors, more particularly to those referring to gold. A locality, namely the Ganges, mentioned by Pliny (B. xxxiii., c. 21), may, perhaps, refer to known sources of the precious metal in the tributaries of the Upper Ganges. His remarks on the quantity of gold in India (B. xxxiii., c. 21) are full of interest.

Regarding iron, he says the best is made by the Seres; some authors suppose them to have been an Indian tribe inhabiting Sarhind, the modern Umbala District, but the balance of evidence is certainly in favour of their having been Chinese. The next quality is from Parthia. Elsewhere he says (B. xii. c. 8) that the Romans obtained steel, together with pearls, at Cape Comorin.

¹ *Vide* Latin Version, vv. 315 and 1107.

His account of the Murrhine on the whole bears out the view as to its nature, stated below on page 89, save that he records (B. xxxvii. c. 7) that "a person of consular rank, who some years ago used to drink out of this cup, grew so passionately fond of it as to gnaw its edges"—a fact not consistent with it being a substance having the hardness of the Chalcedonic minerals.

Regarding amber, he quotes the account by Ktesias, which, as has been shown, refers to shellac, and alludes to the fable of amber being produced from the tears of the meleagrides (guinea-fowl). Another statement of his which I cannot explain is, that the Indians polish amber by boiling it in the grease of a sucking pig.

Adamas.—Under this head the diamond appears to have been included, together with some other stones. "It is," he says (B. xxxvii. c. 15), "the substance that possesses the greatest value, not only among the precious stones, but of all human possessions, a mineral which for a long time was known to kings only, and to very few of them." Where, however, he refers to its hexangular and hexahedral form, he appears to have been alluding to some other mineral; but his mention of splinters as being used by engravers of other stones again points to the true diamond. He says it could only be broken after being steeped in the blood of a he-goat.

Smaragdus.—Twelve varieties are mentioned (B. xxxvii., caps. 16, 17). Some of these may have been emeralds, especially those of the third rank, which are said to have come from Egypt. This locality is considered to have been Mount Zalora, in Upper Egypt, which still produces emeralds, and was probably the only locality for them known by the ancients. With reference to some of the other varieties, I feel no little confidence in suggesting that they may have been jade, but this mineral is also included in his account of *Jaspis*.

Beryls are said to be found in India, and rarely elsewhere (B. xxxvii. c. 20). It is certainly true that they do occur in India, but I am unaware of their being now highly esteemed by the natives, as appears to have been the case in Pliny's time.

Opals, according to Pliny, were alone produced in India. I am not aware of any known source of precious opal in India. His reference is therefore, probably, to some of the common varieties.

Want of space prevents me from further analysing Pliny's

catalogue, the more particularly as it does not add much to what is elsewhere given on previous pages.

THE PERIPLUS OF THE ERYTHRÆAN SEA (*Circa*, A.D. 80–89?)—The author of this work, a Greek merchant, resident in Egypt, is not known to us by name. His statements of the Indian export and import trade are given with a great deal of method and obvious accuracy. The following extracts are from Mr. M'Crindle's translation. The principal ports mentioned are Barugaza, the modern Bharoch, on the Narbada; Barbarikon, on the Indus; Mouziris (Mangalore), and Nilkunda (south of Mangalore), both the last being on the coast of Malabar. First, as regards the exports: Indian iron and sword blades were exported from Arabia to Adouli in Africa. Indian iron is mentioned in the Pandects as an article of commerce, and the Arabian poets celebrate swords of Indian steel—as well they might, since the material of the famous Damascus blades was “wootz,” which was manufactured in an obscure village in the Hyderabad territory.¹

From the ports of Mouziris and Nilkunda gems in great variety were exported; but these, it is expressly stated, were not produced in India, but were brought from Taprobane or Ceylon. They probably consisted of the varieties of what we now call corundum, viz., sapphire, ruby, &c.

Separately, the *Adáμας* is mentioned as being sent from these ports, and it seems probable that under this title we may understand that diamonds, the production of Indian mines, are referred to.

From Barbarikon, on the Indus, a stone called *καλλεανός* was exported. It has been suggested that gold stone or chrysolite was indicated by this name. I cannot think that this is likely to be correct. Chrysolite of value is not, so far as we know, a product of that region: more probably, as has been suggested by Dana, it was turquoise, or an allied mineral now called callianite. If this identification be correct, it probably came through Afghanistan from Persia—the most famous known source of it being at Amsar, near Nishapur in Khorassan. Its occurrence anywhere nearer is extremely doubtful.²

From Barugaza to Egypt vast quantities of *ὀνυχινή* were

¹ *Vide* Economic Geology, p. 340.

² Economic Geology, p. 435.

exported. They reached the seaport from Ozene and Paithana, the modern Ujein in Malwa, and Paithan in Hyderabad. These are still known as the principal sources, among many, where pebbles of onyx and other Chalcedonic minerals are obtained from the detritus of the Deccan basalt.¹ The famous *Μουρρίνη*, which fetched extravagant prices² in the Roman markets, was also obtained in Ozene and exported from Barugaza.

Regarding the identity of this substance, Herman Müller, as quoted by Mr. M'Crindle, remarks:—"Six hundred writers emulously applying themselves to explain what had the best claim to be considered the *Murrha* of the ancients, have advanced the most conflicting opinions. Now it is pretty well settled that the Murrhine vases were made of that stone which is called in German *flusspath* (*spato fluore*"). In spite of a desire not to augment this intolerable number of opinions, I must register an objection to this judicial decision of Professor Müller. Fluor spar happens to be, though so common a mineral in other countries, of the very greatest rarity in India, and there is no record of its occurrence in the Deccan basalts. It is, moreover, a mineral which, while it is susceptible of being made into ornamental objects, is, from its softness, easily injured by wear and tear, and therefore possesses little durability.

On the other hand, at Ujein, a great variety of Chalcedonic minerals are found, and I therefore prefer to follow those of the six hundred writers who have identified one or other of its varieties with the ancient murrha. At the present day cups and vases of carnelian, agate, &c., are obtainable in Bombay; and I think it most improbable that the modern *Akiks*, or lapidaries, who are the direct descendants of those who made the murrhine cups 2000 years ago, ever saw, much less worked, the mineral called fluor spar.

Another argument in support of this identification has been urged by some writers: it is that stone cups and vases, and fragments of them which have been obtained in excavations at Rome, have, on examination, proved to be of this material. None of fluor spar are recorded.

¹ Economic Geology of India, p. 502, where numerous references and a full account of the trade will be found.

² Nero gave for one 300 talents, = £58,125. They were first seen at Rome in the triumphal procession of Pompey.

The Σάπφειρος was, we are told, exported from Barbarikon. If this were the true sapphire of modern times, its export from the most northern port, and, therefore, furthest from the recognised sources of the stone, would in itself be difficult to explain. It has been, however, clearly shown by King [Precious Stones] and Dana [Mineralogy] that the Σάπφειρος of Theophrastus, Pliny, and Isidorus, &c., was what we now call lapis-lazuli. For Pliny says, "*Sappheiros cœruleus est cum purpura, habens aureos sparsos.*" Now lapis-lazuli is characterised by having scattered through the blue mass small crystalline particles of golden-coloured iron pyrites.

As further evidence in favour of this interpretation, there is the fact that there are very ancient mines of lapis-lazuli at Firgamu in Badakshan (not Beluchistan, as has been incorrectly stated by some writers), and it might very easily have been brought by caravans through Afghanistan to Barbarikon. The mines alluded to are described by Wood in the account of his journey to the Oxus, and both Marco Polo and Tavernier refer to the occurrence of the mineral in that region.

Captain Hutton, in 1841, found it on sale at Kandahar. He mentions several places in Afghanistan where it was said to occur.¹

The Υάκινθος, on the other hand, which was exported from the southern ports Mouziris and Nilkunda, is thought by some to have been the sapphire, as also was the hyacinthus of Pliny (xxxvii. 44), and its variety the asteria (*id.* xxxvii. 49). The *yakut*, as the name is now understood in India, is either a ruby, or the inferior spinel (more properly called *laal*), or even a garnet. According to Salmasius, quoted by Mr. M'Crindle, the Υάκινθος is the ruby, while according to Solinus it would appear to be the amethyst. This is a point on which Indian geology throws no certain light, as neither rubies nor sapphires appear to have been indigenous products.²

In the Persian work on precious stones quoted hereafter, it will be seen that in the thirteenth century the same generic name was applied to the ruby, sapphire, and other varieties of corundum.

¹ *Vide* Economic Geology of India, p. 528.

² It should be stated that there have been recent discoveries of sapphires in the Himalayas, but there is no evidence that they were ever found there before.

With reference to the imports which are of interest as indicating the requirements, if not of the whole of India, at least of that portion of Western India into which they were carried, we find the following enumeration:—

Silver: Costly plate, from Egypt to Barugaza.
 Gold and silver coins, from Egypt to Barugaza.
 Gold bullion, from Arabia to Barugaza.
 Arsenic, from Egypt to Mouziris and Nilkunda.
 Tin, from Egypt to Mouziris and Barugaza.
 Lead, from Egypt to Mouziris and Barugaza.
 Antimony sulphide, from Egypt to Mouziris and Barugaza.
 Copper, from Egypt to Mouziris and Barugaza.

The import of silver plate at this early period is remarkable. Whether it has been kept up in modern times, so far as the requirements of the natives are concerned, I cannot say, but the other substances are still largely imported. In four years recently, for instance, upwards of 200 tons of arsenic, in the forms of white arsenic, orpiment, and realgar, were imported; and the antimony sulphide, called *surma* by the natives of India, is largely used for anointing the eyes.

Χρυσολιθος was also exported from Egypt to all four ports. It appears to be tolerably clear that this mineral was not our modern chrysolite, but was the topaz, while the topazion of Pliny was in part at least chrysolite, as he says it yielded to the file and wore with use; but his mention of a statue, 4 cubits high, which was made of it, indicates a crystal of a size quite unheard of: probably this was either beryl or jade.

PTOLOMEY (A.D. 140–160). *Diamonds*.—The *Adamas* river of Ptolomey, according to Lassen's analysis of the data, was not identical with the Mahanadi, as I have suggested in my "Economic Geology,"¹ but with the Subanrikha, which is, however, so far as we know, not a diamond-bearing river, nor does it at any part of its course traverse rocks of the age of those which contain the matrix of the diamond in other parts of India. This *Adamas* river was separated from the Mahnada (*i.e.* Mahanadi) by the Tyndis and Dosaron; the latter, according to Lassen, taking its rise in the country of Kokkonaga (*i.e.* Chutia Nagpur), and to which the chief town, Dosara (the modern Doesa), gave its name. But,

¹ Economic Geology, p. 30.

according to this view, the Dosaron must have been identical with the modern Brahmini, which, in that portion of its course called the Sunk (or Koel), included a diamond locality. I cannot regard this identification as satisfactory, as it does not account for the Tyndis intervening between the Dosaron and Mahnada, since, as a matter of fact, the Brahmini and Mahanadi are confluent at their mouths.

Lassen, however, identifies the Dosaron with the Baiturnee, and the Tyndis with the Brahmini. This destroys the force of his remark as to the origin of the name of the former, since at its nearest point it is many miles distant from Doesa.

Another locality of Ptolomey's, said to be situated on the Ganges, in the country of the Sabaræ, may, perhaps, be identical with Tavernier's Soumelpour on the Koel; it was situated some miles distant from the Ganges. Wherever it was, it produced most diamonds.

A third locality mentioned by Ptolomey has been variously identified with Sambalpur and Weiragarh¹ in West Gondwana, the position of which last was not correctly known to either Ritter or Lassen, though the fact of the existence of diamond mines there had been recorded by Ferishta and Abdul Fazl.

Ptolomey stated that Ceylon produced the beryl, hyacinth (? = sapphire), and all sorts of metals; the last is, however, not the case, Ceylon being rather poor in metallic ores.

Under the name Bathana, a source of the onyx is mentioned by Ptolomey; this appears to have been a well-known locality at Paithan on the Godaveri, which was alluded to as Plithana by the author of the *Periplus*.

The sardonyx mines of Ptolomey are probably identical with the famous carnelian and agate mines of Rajpipla, or rather, as it should be called, Ratanpur.

The loadstone rocks of India, which attracted so much notice by several early writers, were known to Ptolomey; they may possibly be identified with certain hill ranges in Southern India which mainly consist of magnetic iron.² Early writers connected their presence with the fact that many of the vessels and boats engaged in the Indian coasting trade contained no iron in their construction,

¹ See *Economic Geology of India*, p. 37.

² *l. c.* p. 335.

and hence probably arose the well-known fable about the injury to shipping caused by the loadstone rocks. The surf boats, however, have no iron in their construction, simply because bolts or nails would render them too rigid; nor have the vessels of the Laccadives and Maldives, because iron ores do not occur in coral islands.

The identity of *Argyre* (where, according to Ptolomey, there were mines of silver), *Chrysé chersonesus*, *Chryse chora*, and *Chalkitis* have recently been discussed by Colonel Yule.¹

The first he proves to be Arakan, where, however, there are no silver mines; and considering the geological structure of the country, it is almost certain there never were any. I have been recently informed by General Sir Arthur Phayre that Argyre is probably a transliteration of an ancient Burmese name for Arakan. It seems likely, therefore, that it was from putting a Greek interpretation to this name that the story of the silver mines owed its origin. According to Colonel Yule, the Arabs probably adopted their ideas from the Ptolomaic charts. With regard to the other localities, he says, "The golden Chersonese is specifically the protuberant delta of the Irawadi, Pegu, the *Suvarna bhumi*, or golden land of Ancient India, whilst the golden region behind is Burma, the oldest province of which, above Ava, is still formally styled in State documents, *Sona paranta*, "Golden frontier." Ptolomey's *Chalkitis*, also, or copper region, approximates curiously to the *Tampa-dipa*, or Copper Island of the Burmese State phraseology, "a region which embraces Ava and the ancient capital Pagan."

These identifications remove from the region of probability what has sometimes been urged, that Argyre and Chryse were countries which supplied India with large quantities of silver and gold.

ARRIAN (*Circa*, A. D. 146.)—The first part of Arrian's *Indika* was founded on the works of Megasthenes and Eratosthenes, and the second on an account of the voyage made by Nearchos the Kretan from the Indus to the Pasitigris. The parts of this compilation which bear upon our present subject have already been anticipated in the description of Megesthenes' writings, and need not, therefore, be repeated.

The authors whom I have consulted with reference to the

¹ Proceedings of the Royal Geographical Society, 1882, p. 654.

Roman trade with India are: Robertson,¹ Renaud,² and Priaulx.³ This trade, which succeeded that of the Greeks, came to an end in the sixth century. Besides what has already been independently quoted from the pages of Pliny and Ptolomey, there do not appear to be any records of much importance bearing upon the present subject.

An account of India, written for Palladius towards the close of the fourth or beginning of the fifth century, makes special reference to the loadstone rocks, possibly quoting from Ptolomey. In the fifth century Hierocles speaks of the Brahmins as being clothed in garments made from a soft and hairy filament obtained from stones. This, it seems most probable, owed its origin to some mistaken notion as to the origin of cotton rather than to the use of woven asbestos, as has been suggested.

Under the Emperor Justinian, in the sixth century, Cosmos (surnamed Indicopleustes), an Egyptian merchant, made several voyages to India, and recorded his experiences in a work called *Christian Topography*, in which some account of the export trade of India is given. He mentions how the Persians became rivals of the Romans at the Indian ports, and how the precious commodities were conveyed from thence up the Persian Gulf, and were distributed by means of the Euphrates and Tigris. Gradually the trade to Constantinople, the then seat of the Romans, was thus diverted.

Eighty years after the death of Justinian, Mahomet published his new religion, and it was not long before the Arabians spread themselves as conquerors over the countries adjoining their own, thence spreading by sea and land over an ever-widening area. To a great extent they wrested the Oriental trade from the Persians; they established a mart at Bussora, which speedily rose to an importance scarcely exceeded by that of Alexandria in the height of the Greek and Roman period. So little is known of the details of this trade, that there is only barely sufficient evidence for the

¹ *Historical Disquisition concerning the Knowledge which the Ancients had of India.* London: 1809.

² *Relations Politiques et Commerciales de l'Empire Roman avec l'Asie Orientale . . . pendant les cinq premiers siècles de l'ère Chrétienne.* Jour. Asiatique, 6th ser., 1863, tome 1.

³ "Apollonius of Tyana."

conclusion that, as regards the mineral productions, it did not differ materially from that which preceded it in the hands of other nationalities.

The most important work giving an account of India at about this period is the famous voyage by a Mahomedan traveller, with annotations by another, called Abu Seid al Hassan of Giraf.¹ Their account is confirmed by another Arabian called Massoudi, whose universal history bears the fantastic title, *Meadows of Gold and Mines of Jewels*.

The effect of this absorption of the trade of the Red Sea was to deprive the European nations of that highway of commerce, and the requirements of Europe had to be brought to Constantinople from India and China by long and tedious overland journeys, which became especially arduous during the Crusades. This state of things continued till the discovery by the Portuguese in the fifteenth century of the long sea passage round the Cape of Good Hope.

From various sources, however, we are enabled to pick up fragments of information referring to different centuries included in this interval. Thus a Sanskrit work called the *Brhat Sanhita*,² which, it is believed, was written in the sixth century, contains a very detailed account of diamonds, their varieties, qualities, and attributes. Of especial interest is a list of eight localities where diamonds were found. Most of these I have succeeded in identifying with sites where diamond mines are known to have been worked.³ With regard to some of the localities, however, it is more than doubtful whether they ever produced diamonds.

The first Englishman who visited India appears to have been Sighelmas, Bishop of Shirburne, who was sent thither, in the year 883, by King Alfred, to visit the famous Christian named St. Thomas. This Bishop, we are told, made his journey in comfort, and brought back with him "many splendid exotic gems and spices, such as that country plentifully yielded"⁴—a fact in itself of no great importance, save that it is a link in the chain.

¹ First translated in A.D. 1718 into French by M. Renaudot.

² Translated by Dr. Kern, *Jour. Roy. Asiatic Society*, vol. vii. N.S. 1875, p. 125.

³ *Economic Geology of India*, p. 2.

⁴ Recorded by William of Malmesburie in *De Gestis regum Anglorum*. Book ii. cap. iv. *Vide* Hakluyt's *English Voyages*.

Somewhere between the years 1067 and 1081 Marbodius wrote a poem entitled *De Lapidibus Preciosis*, in which he gave expression to the then prevailing ideas as to the sources and qualities of the diamond. Far India is recognised as its native place, and the use of splinters of it for engraving upon other gems is alluded to. Its hardness is said to yield to steeping in goat's blood—a fable already quoted from Pliny. How this idea originated it is not easy to say; possibly it may be connected with the sacrificial offerings which preceded the search for diamonds, as will be described on a future page.

In the eleventh century, according to Dr. Burnell, wealth must have abounded in Southern India, because it was then that the numerous *Sivoid* temples were built; and in the thirteenth century the great *Vishnu* temples were erected. Regarding the famous inscription on the Tanjore temple, he has written as follows:—

“The full importance in Indian history of Vera Cola's reign is only to be gathered from this inscription; but it contains other information also of great value. It proves, *e.g.*, that in the eleventh century gold was the most common precious metal in India, and stupendous quantities of it are mentioned here. Silver, on the other hand, is little mentioned; and it appears that the present state of things, which is exactly the reverse, was only brought about by the Portuguese in the sixteenth century.

“I submit that the great abundance of gold spoken of in the inscription can have arisen only from mines, and that in the terrible convulsions caused by the irruption of Moslem invaders from the north and Europeans from the west, the position of these gold-fields was lost sight of.”

It has been remarked upon this, that* “the full significance of this statement as affecting Southern India can be understood only when taken in connexion with the large areas which are known to have been worked by the natives. It seems to leave little room for doubting that the reefs and soils when first opened up were extremely rich, and that the soils as we find them now have been impoverished by repeated washings.

“In the year 1293, Allahud-din, afterwards Emperor of Delhi,

* Brough Smyth: Report of Gold Mines of South-East Wynaad, &c.

took the city of Deogarh, but the citadel still held out. Subsequently Allah raised the siege, on receiving a ransom, the amount of which may well appear incredible, 15,000 lbs. of pure gold, 175 lbs. of pearls, 50 lbs. of diamonds, and 25,000 lbs. of silver, being enumerated among the items. So much appears certain, that Allahu'd-din levied an enormous sum upon Deogarh, and that consequently it must at that time have been a very great city and rich emporium."¹

It has been suggested that this wealth must have been acquired by working the ancient mines of Southern India.

MAHOMED BEN MANSUR (thirteenth century).—The remarkable Persian work on Precious Stones by this author was translated first into German by Joseph von Hammer.² The following facts are from an English version³ :—

Diamond.—Seven kinds are recognized, namely, (1) white transparent; (2) the pharonic; (3) the olive-coloured, the white of which inclines to yellowish; (4) the red; (5) the green; (6) the black; (7) the fire-coloured.

In spite of this elaborate classification, Mahomed's knowledge of the *habitat* is very vague. He says:—"In the eastern parts of India is a deep ravine, inhabited by serpents, where diamonds are produced. Some people suppose that it is found in the *yakut* mines."

Here there is an obvious allusion to the diamond myth—to be described hereafter.

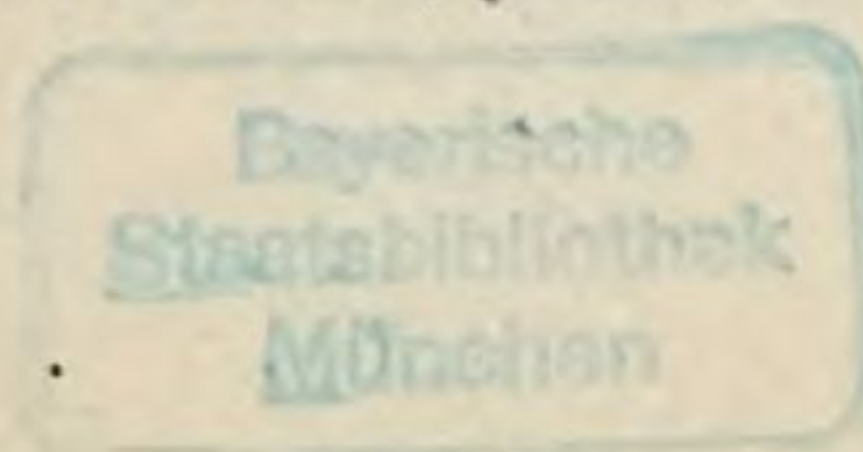
Corundum (Senbade), he says, quite correctly, is next in hardness to the diamond, and is of a reddish or bluish colour. The mines were situated in India, Zanzibar, Siwas, Kerman, Nubia, and Ethiopia. The best kinds were from Siwas and Nubia.

Yakut.—Under this title are included six classes: (1) red (*i.e.* ruby); (2) yellow (*i.e.* Oriental topaz); (3) black (*i.e.* pleonaste); (4) white (*i.e.* white sapphire); (5) green (*i.e.* Oriental emerald); (6) blue, or smoke-colour (*i.e.* sapphire). Of these classes sub-divisions into varieties are given. It is certainly a most remarkable fact that at so early a period the essential identity of these precious stones—a fact only comparatively

¹ A Hand-book for Madras. John Murray, 1859, p. 94.

² Mines de l'Orient, vol. vi.

³ Asiatic Journal, vol. ix. 1820, p. 345.



recently ascertained by chemical examination — should have been known to the Persians. The hardness and other characters are correctly stated also by Mahomed. The locality of the principal mines is stated to be the island of Saharan, which is sixty-two farsanges in diameter, and lies forty farsanges behind the island of Ceylon. The *yakuts* are found there in a high mountain. This jumble is not easy to explain, the true locality being Ceylon itself, which is noted for its high mountains, culminating in Adam's Peak.

Another locality is also mentioned, Tara, near Cairo, where mines were discovered A.D. 1270.

A stone, called by Mahomed the *chamahen*, should come here, if, as is stated, it is next to the diamond in hardness; but this is inconsistent with another assertion that, when rubbed on a hard stone, it colours it red. When broken, it divides into branches. The most beautiful is blackish-red; it is found in the district of Karak. But for the first statement I should be inclined to identify this as jasper.

Spinel (Laal).—Of this there are four classes, namely, the red, yellow, violet, and green. Of the red there are eight varieties. Mahomed only mentions one mine, that in Badakshan, the capital of which, Balkh, gave origin to the term “Balas.” His account, which is as follows, was unfortunately not available to me when giving a *précis* of information regarding the locality¹:—“At the time of the caliphate of the Abbasides, a mountain at Chatlan was rent open by an earthquake, where there was found the *laal* of Badakshan, bedded in a white stone. It is very hard to polish, and it was a long time before it could be smoothed, till it was at length accomplished by means of the gold marcasite called *ebrendshe*. Smaller stones are found in the bed round a large one, like the seeds of a pomegranate. The miners call this bed of the Spinel *maal*. There were found in the mines first red, then yellow *laal*, and it belongs to the kinds of the *yakut*.” The discovery of these mines by a landslip finds a parallel in a recent discovery of sapphires in the Himalayas.² The white stone which formed the matrix is probably limestone. Wood, in 1837, stated that the matrix was a red sandstone or a limestone impregnated with magnesia, but he did not personally visit the mine.

¹ Economic Geology, p. 430.

² Records of the General Survey of India, vol. xv., 1882, p. 138.

Turquoise (Firuse)—Obtained at Nishabar, Ghasna (? Ghuznee), Irak, Kerman, Chouresm, the first being the most valued. There is, therefore, no Indian locality : such seems to be still the case.

Talc (Sitarei semin = star of the earth)—Two kinds—one found in the air (? superficially), and the other in mines. Mahomed says —“artificial pearls are made from it, and it does not burn or calcine with fire. If you dissolve it and rub the limbs with it, it makes them fire proof. Talc can neither be pounded in mortars nor broken to pieces with hammers. The way to dissolve it is to boil it with beans ; to wrap it then in a piece of linen. If dissolved talc is mixed with a little resin and saffron, and used as ink, it makes a gold ink, and, without saffron, silver ink.”

Rock Crystal (Bellor).—Of this two kinds are mentioned, one being clear, and the other dark-yellowish. The added statement that they can be melted like glass, and then coloured so as to imitate the *yakut*, *laal*, or emerald, is unintelligible, since rock crystal by itself is a most infusible substance. Perhaps what is meant is, that siliceous sand was used in the manufacture of the glass or paste of which false stones were made.

Mahomed says that at Ghasna, there were four crystal vessels, each of which could contain two skins of water. He mentions that crystals of other minerals and wood (probably crystals of tourmaline) often occurred enclosed in the *bellor*. Some fanciers, we are told, prefer the Arabian to the Indian variety.

Amethyst (Dschemst)—Four kinds : (1) deep rose-colour and sky-blue ; (2) pale rose-colour and deep azure ; (3) pale rose-colour and sky-blue. It was much esteemed by the Arabs. Mahomed does not refer to its occurrence in India, but states that it was obtained near the village of Safwa, three days' journey from Medina. Wine drunk out of a goblet made of amethyst does not intoxicate, upon which Mahomed's translator remarks :—“This opinion was also current in Europe, and the name *dschem* or *dschemsshid* is connected with it. The Greek word *αμεθυστος* also means “unintoxicated,” but it is originally derived from *dschemest*, as the jasper from *jaschep* ; hyacinth from *yakut* ; emerald from *Semerrud* ; pearls (Margarita) from *merwarid* ; turquoise from *firuse* ; lapis-lazuli from *ladschwerd* ; sardonyx from *sard* ; talc from *talk* ; chalk from *kals*.”

Emerald (Semerrud).—Seven varieties or different shades are

recognised. The mine was situated on the border of Negroland, in Egyptian territory. The matrix of the gem was talc and red earth. It seems probable that this was the source of the emeralds which went to India, and also supplied the Greeks and Romans. A soap-green emerald was also found at Hedshas, in Arabia.

Owing to the fact that jade was not recognised as a distinct mineral until introduced into Europe from the New World, the older writers sometimes, on account of its hardness and transparency, spoke of it as emerald, while others applied to it the term jasper. There can be no doubt that jade is meant by the following, not jasper, as his translator has it:—

Jaschep, or *Nussz*.—Five kinds: (1) white and light; (2) whitish yellow; (3) black-green; (4) transparent black; (5) dust-colour.

Mahomed adds that in China they make false *jaschep*, which is distinguished by its smoky smell, and that there are two mines in China called respectively *Ak-Kash* which produces light, and *Kut-Kash* which produces dark *jaschep*. It is found on the frontiers of Kashgar, Kerman, and Arabia.

Kash is the name for jade current in Eastern Turkistan, and *su* or *zu* is the name by which it is known to the Chinese, who esteem it more highly than do the people of any other nation.¹

Chrysolite? (*Sheberdshed*).—This is said by Mahomed to be obtained in the same mine as the emerald, of which it is a variety according to some authorities. If so, it cannot be what is now known as chrysolite, which is the transparent variety of olivine.

Mahomed mentions a number of other minerals, among them several ores. Of the magnet he says there are four kinds, namely, the iron, gold, silver, and tin, which attract these metals respectively; possibly by this it is meant to be conveyed that ores ascertained to contain these metals exhibited magnetic properties.

The following statements, regarding the knowledge possessed by the Persians of the relative specific gravities of some precious stones, are of interest:—

“Abu Rihan is said to have found by experiment that a muskal (= $1\frac{1}{2}$ drachms) of blue *yakut* (sapphire) is equal to five dank and a tissu of red *yakut* (ruby), or to five dank and two and

¹ Economic Geology, p. 516, *et. seq.*; and also p. 109 of this Paper.

a-half tissu of *laal* (spinel), and that four dank, minus a tissu of coral, are equal in size to four dank, minus two tissu of onyx and crystal. The mode of discovering the size and weight is the following:—A vessel is filled with water, and the stones thrown singly into the water; the quantity of water which is expelled from the vessel by means of each stone is equal to the room it occupies.”

MARCO POLO.—A notable authority on the mineral production of India during this same thirteenth century is the famous Venetian traveller, Marco Polo. In reference to the diamond, he states that it was only obtained in what he designates as the kingdom of Mutfli—a name which has been identified by Colonel Yule with Motupalle, a still existing port in the Guntur District of Madras. The proper name of the kingdom was Telingana, which therefore included the so-called Golconda mines of the Kistna Valley; but Marco Polo extended to it that of the town or post which he visited. It is noteworthy, as testimony of an early trade, that Marco Polo states that “those diamonds brought to Europe are, as it were, the refuse of the finer stones, which go to the Great Kaan and the other kings and princes of India.” He describes three methods as being followed in the search for diamonds:—

First: After the rains the beds of torrents from the mountains were searched; these localities were infested with venomous snakes.

Second: Pieces of meat were thrown down from the tops of mountains into inaccessible valleys; these pieces of meat were pounced upon and carried up to the tops of mountains by white eagles, and, when recovered, diamonds were found sticking to them. This story, made familiar to all by the travels of Sindbad the Sailor, is one of great antiquity. The earliest mention of it, according to Colonel Yule, is by St. Epiphanius, Bishop of Salamis, in Cyprus, who, in the fourth century, wrote a treatise on the twelve jewels in the breastplate of the High Priest. The tale, as told by him, however, refers to the jacinth, not to the diamond.

A list of the authors who have alluded to this tradition will be found in Colonel Yule's edition of Marco Polo.¹ Its origin, as

¹ Vol. ii. p. 298.

first suggested by me,¹ I shall discuss in connexion with the account given by Nicolo Conti.

Third: This method, which may be described as a corollary of the second, consisted in searching the birds' droppings and intestines for diamonds which they had swallowed with the meat.

Marco Polo, in various parts of his book, refers to other precious stones, especially to the Balas rubies and "azure" or lapis-lazuli of Badakshan. The value of the former was kept up by a limit being imposed by the king on the out-turn. The latter, he says, occurred in a vein like silver, and was the finest in the world.

In reference to gold and silver² there are several important facts recorded; among others, the enormous extent of the accumulation of gold in the treasuries of the princes of Southern India, upon which Colonel Yule remarks, after speaking of the spoil carried off by Allahud-din, that "some years later, Mahomed Tuglak loads two hundred elephants and several thousand bullocks with the precious spoil of a single temple." And a further statement, given on the authority of Wassaf, is, that "Kales Dewar, Raja of Malabar, about the year 1309, had accumulated 1200 crores of gold, *i.e.* 12,000 millions of dinars."³

Marco Polo distinctly mentions copper, gold, and silver as being imports into Malabar and Cambay from Eastern countries in his time.

FERISHTA.—Our next authority is the Indian historian, Ferishta, who wrote in 1425. What he says on the subject is chiefly of importance as confirming other evidence of the great wealth possessed by the princes of Southern India in the form of stores of precious stones and bullion. It has already been partly quoted on page 96. He refers to now long-deserted diamond mines in the Central Provinces of India,⁴ which I have been able to identify as having been situated at Wairagarh, in the Central Provinces.

NICOLO CONTAI.—The last writer of what may be called the fabulous period, which closed with the fifteenth century—at least in so far as regards the diamond fable—was the Venetian, Nicolo Contai,

¹ Jour. As. Society, Bengal, vol. I. pt. ii. p. 31.

² *G.*, vol. ii. pp. 276, 284; *S.*, *ibid.* pp. 325 and 327.

³ Marco Polo, vol. ii. p. 284, note 6.

⁴ History. Ed. by J. Briggs. London: 1819, vol. ii. p. 261.

an account of whose voyage is given by Baptista Ramusio¹ in his book of Voyages and Travels, on the authority of Messer Poggio, Fiorentino. The locality where the diamonds were found was at Abnigaro, fifteen days' journey northwards from Bisnagar.² As to its identity I am not yet quite satisfied. We are told that the mountain which produced the diamonds was inaccessible, being infested with serpents, but was commanded by another mountain somewhat higher. "Here, at a certain period of the year, men bring oxen, which they drive to the top, and having cut them into pieces, cast the warm and bleeding fragments upon the summit by means of machines which they construct for the purpose. The diamonds stick to these pieces of flesh. Then come vultures and eagles flying to the spot, which seizing the meat for their food, fly away to places where they may be safe from the serpents. To these places the men afterwards come and collect the diamonds which have fallen from the flesh."

He then describes a different process, which is simply that of washing for diamonds in the beds of rivers. For as far back as we have any certain knowledge of them, the diamond miners have all belonged to one or other of the non-Aryan or aboriginal tribes, who regard the mines as being the special property of the blood-thirsty goddess, *Lakshmi*, whose cruel nature requires much propitiation.

To this day sacrificial offerings are made to her on the opening up of mines, of whatever sort, and occasionally the meat is placed on an altar-like scaffold; and in India, as a matter of course, vultures and kites, with other raptorial birds, would carry away and devour whatever portions of meat they could seize upon.

Out of this custom it seems to me most probable that the tradition grew which has now attained to such a respectable antiquity. Lookers-on, unacquainted with the semi-savage rites, regard them as essential parts of the search for diamonds.

UERTOMANNUS.—In the year 1503, Lewes Uertomannus, who is described as a Roman gentleman, travelled in Western and Southern India. The account of his travels contains some interesting parti-

¹ Delle Navigazioni et Viaggi. Venice: 1613.

² These two names are so written in Ramusio's volume, but in a translation of the passage, published by the Hakluyt Society, they are given as Albenigaras and Bizengulia.

culars bearing on our present subject.¹ Of Cambaia he says (p. 381): "In this region is also a mountaine where the onyx stone, commonly called corneola, is founde, and not far from thence also another mountaine where the calcedony and diamant are founde." If by *diamant* the diamond is meant in this passage, the fact is noteworthy, as the Ponassa of Ptolomey is probably identical with the modern Ponassa in this region. At the same time a doubt must be expressed as to true diamonds having been ever found there. Further on our author says (p. 383): "Sixe miles from the city of Decan (? Bisnagar) is a mountaine where diamonds are digged. It is compassed with a wall and kept with a garrison."

Uertomannus mentions that two European dealers in precious stones, named respectively John Maria and Peter Antonie, resided at Calicut with the king's licence. They had acquired a fair diamond of 32 carats, worth 35,000 crowns, a pearl of 24 carats, and 2000 rubies, some of 1 carat, and some of $1\frac{1}{2}$ carats. On their attempting to depart secretly with their treasures to Cannanore, they were murdered by order of the king.

Under the heading, "Of the Diamondes of the Old Myne," our author says (p. 424):—"These diamondes are found in the first India, in a kingdom of the Morres, named Decan, from whence they are brought to other regions. There are also found other diamonds which are not so good, but somewhat whyte, and are called diamondes of the new myne, which is in the kingdom of Narsinga (Lower Kistna). They of the old mine are not pollyshed in India, but in other places. There are made lykewise in India false diamondes of rubies, topazes, and white sapphires, which appear to be fine, and are also found in the island of Zeilan (Ceylon). These stones differ in none other save that they have lost their natural colour." In another place he gives information as to the local prices of other precious stones, as rubies, spinel, sapphires, topaz, &c.

Next follow a group of authors, the accounts of whose travels are to be found in Baptista Ramusio's above-mentioned work. The first of them is Andrea Corsali, Fiorentino, whose letter,

¹ The History of Travel, &c., done into English from the original Latin. By R. Eden and R. Willes. Lond.: 1577.

addressed to Signor Guliano de Medici, Duca di Fiorenza, is dated Cochin, 6th January, 1515; it contains only a few unimportant facts bearing upon this subject.

Another of these authors is Ludovico Barthema, whose information is almost identical with that already quoted from Lewes Uertomannus. The precise date of Barthema's work I have been unable to ascertain.

From the book of Odarodo Barbosa, which refers apparently to a period about the year 1519, and to a voyage to India made by way of the Cape of Good Hope, we learn that at Bisnagar, *i. e.* Vijayanagar, jewels brought from Pegu and Ceylon were on sale in great abundance, as also were diamonds from Narsinga. This author gives also a full account of the values, &c., of a number of precious stones, namely, rubies, spinel, diamond, sapphire, topaz, turquoise, hyacinth, and emerald, and mentions the localities where they were obtained, but these details are too voluminous for reproduction here.

GARCIAS AB HORTO.—Our next authority is Garcias ab Horto, a physician resident at Goa, who, in 1565, produced a work in Portuguese, containing a considerable amount of interesting and—much of it, though not all—obviously accurate information on our present subject.¹

He tells us that there are two or three localities near Bisnagar (Vijayanagar) where diamonds were obtained, the industry being a considerable source of revenue to the king, as all stones above 30 mangelis (= 150 grs.?) became his property. Another mine also in the Decan produced excellent diamonds. It was situated in the lands of a native prince, near the territory of Imadixa (*i. e.* of Ahmed Shah?). This last was probably identical with the mine at Wairagarh, in the Central Provinces.

Garcias treats with scorn the old fable of the valley inhabited by serpents, and moreover points out that a Jesuit father, Francois de Tamara, who had repeated it, was therefore not worthy of credence, when he stated that diamonds were to be found in Brazil. The statement is of importance when it is remembered that the first diamond mines in Brazil were not opened up till 1728, or more than 160 years later. It may be added that the version of the fable just alluded to is that one where the serpents

¹ De Arom. et Simp. Historia, a Latin version by Clusius of Antwerp, 1567.

guard the jewels, and while they are engaged eating the meat thrown to them, the diamond-seekers are enabled to pick up the stones. Garcias speaks of several large diamonds which were known to exist in his time; two weighed 140 and 120 mangelis respectively (*i. e.* 700 and 600 grs.). Far exceeding these in size was one which he had heard of from a native who had seen it; it was said to be equal in size to a fowl's egg; it weighed 250 mangelis, or 1250 grs. This was, according to Tavernier, who wrote a century later, the form of the Great Mogul diamond when originally found. So that it seems quite possible that this casual notice by Garcias is the earliest mention of that famous stone.

Even in the time of Garcias it would seem that the tailings from earlier washings were sometimes rewashed with good results. He states that Lispor, in the Decan, was a principal mart for the sale. (Can this have been Vizapur or Bijapur?)

The geographical limits of Balaghat—a name used not only by Garcias, but also by some other writers—it would, probably, be impossible to closely define now. The name is still conserved as that of a particular district, but in early times it seems to have been applied to all the region in Southern India *above* the *Ghâts*, which was sometimes also called the Carnata, a name now, however, restricted to a district *below* the *Ghâts*.

With reference to other precious stones, Garcias states that a false smaragdus (emerald) was made of glass in Balaghat and Bisnagar. He distinguishes four varieties of ruby, as the true, carbuncle, balas, and spinel. Of sapphires he says two kinds were found in Calicut, Cannanore, and several places in Bisnagar. We have no knowledge of true sapphires ever having been obtained in these districts. Both hyacinth and garnet were found in Calicut and Cannanore, the latter being distributed throughout the whole of Cambay and Balaghat. Beryl was found in Cambay, Martaban, and Pegu, also in Ceylon: glasses and vases were made from it.

Garcias states that the Murrhine Cup was made of jasper; more correctly, perhaps, it was made of carnelian, as suggested on a previous page.

CÆSAR FREDERICK.—About the year 1567, a traveller named Cæsar Frederick¹ visited Western and Southern India. In a translation from his original account we find the following passage:—

¹ A translation of the account of his travels is given in Hakluyt's *Voyages*, vol. ii. 1599, p. 213.

“The rubies, saphyres, and the spinels be gotten in the kingdom of Pegu. The diamants come from divers places, and I know but three sorts of them. That sort of diamants that is called *chiappe* cometh from Bezeneger. Those that be naturally pointed come from the land of Delly and Iawa (by which we must understand Borneo), but the diamants of Iawa are more waightie then the other. I could never understand from whence they that are called *balassi* come.” The signification of *chiappe* is uncertain. The naturally-pointed stones probably came from Chutia Nagpur, or Kokrah, as it was then called, since Tavernier describes the stones from that region as being of this character, and it is believed that they were taken to Delhi. The term “balas” was applied to the spinel rubies from Badakshan. Possibly, it may have been used for those diamonds which had a roseate tinge.

On another page Frederick says:—“Also, five days’ journey from Bezeneger, is the place where they get diamants. I was not there, but it was told me that it is a great place, compassed with a wall, and that they sell the earth within the wall for so much a squadron, and the limits are set how deepe or how low they shall digge. Those diamants that are of a certain size, and bigger then that size, are all kept for the king. It is many years ago since they got any there, for the troubles that have been in that kingdom.”

FITCH AND NEWBERRY.—The famous traveller, Ralph Fitch, and his companion, Newberry, have left on record an account of their journeys in India, which refers to the years about 1583.¹ In reference to precious stones, the following are the most important passages:—Belleragan, the modern Belgaum, was said to be “a great market of diamants, rubies, sapphires, and many other *soft* (*i.e.* precious) stones.” We are told that a jeweller named William Leades, who was one of their party, remained behind them in the service of the King of Cambay.

The next passage explains the use of the name Iawa, or Java, by Cæsar Frederick, and others:—“Laban (*i.e.* Borneo, the name being retained in Labuan) is an island among the Iawas, from whence come the diamants of the new water, and they find them in the rivers, for the king will not suffer them to digge the rock.”

¹ Hakluyt's English Voyages, vol. ii. 1599, p. 253.

Speaking of Patanaw (Patna) on the Ganges, below Banaras, it is said :—" Here at Patanaw they find gold in this manner. They digge deepe pits in the earth, and wash the earth in great bolles, and therein they find the gold, and they make the pits round about with brick, that the earth fall not in." I cannot but think that there is a mistake here, due to an account of gold-washing in the country to the south having been mixed up with a description of the method of sinking ordinary irrigation-wells in the neighbourhood of Patna. It is not likely that gold was ever found in sufficient quantity in the Gangetic alluvium, near Patna, to repay the cost of searching for it.

ABDUL FAZL.—Here we may turn aside again from European authorities to an Oriental writer, who, being a Mahomedan like the already quoted Ferishta, presents us with much more useful and matter-of-fact statements than are to be found in any works by Hindus. Abdul Fazl, the author of the *Ain-i-Akbari*, written in 1590, refers to the occurrence of and working for several minerals, especially diamonds, gold, and iron. The diamond mines at Beiragarh, in Gondwana, which he mentions as having been taken possession of by the ruler of Kullem, or Chanda, were probably the same as those already mentioned by Ferishta. In any case, it is certain that Beiragarh may be identified with the modern Wairagarh in the Central Provinces, where traces of the mines are still to be seen.

Gold was obtained, he says, in certain streams in Kashmir by pegging down, under water, the hairy skins of animals, which served to arrest the auriferous dust in its descent with the current. Long ago it was suggested that such skins were the origin of the idea of the skins of the gold-digging ants, mentioned by Nearchos and others, but the explanation given on a previous page is the more probable one. He alludes to the "steel" mines at Nirmal, which can be identified with a locality in Hyderabad, where a high quality of steel was prepared, most of which found its way to Persia, for manufacture into the Damascus swords, to which reference has already been made.

The enormous salt deposits of the Punjab are noticed by Abdul Fazl; and here may be quoted a passage from Strabo,¹ which should have appeared on a previous page :—

"It is said that in the territory of Sopeithes there is a moun-

¹ B. xv., chap. i. s. 30.

tain composed of fossil salt sufficient for the whole of India. Valuable mines also both of gold and silver are situated, it is said, not far off, among other mountains, according to the testimony of Gorgus, the miner of Alexandria." Since this salt crops out at the surface, and in Kohat especially, can be easily quarried, it is only natural that it should have attracted attention in the very earliest times.

GOEZ.—Recently I came upon a work, dated 1602, and entitled *Travels of Benedict Goetz from Lahore, in the Mogol's Empire, to China, in 1602*,¹ which contains perhaps the earliest account, by a European author, of the production of jade in Kashgar. He says:—"The commodity best for carrying from Hirakan (*i.e.* Yarkand) to Katay (China) is a certain shining marble, which, for want of a fitter name, Europeans call jasper. The King of Katay buys it at a great price, and what he leaves the merchants sell to others at exceeding great rates. Of it they make vessels, ornaments for garments and girdles, with other toys, whereon they engrave leaves, flowers, and other figures. The Chinese call it *tushe*.² There are two kinds—one more precious, like thick flints, which are found in the river Kotan, not far from the city royal;³ the other meaner sort is dugged out of quarries and sawed into slabs about two ells in breadth. The hill where they are dug, called Kosanghi Kasho, or the stony mountain, is twenty stages from the same mountain. This marble is so hard that they must soften it with fire to get it out of the quarry. The king farms it every year to some merchant who carries provisions for the workmen for that space of time."

Goez mentions (p. 647) that besides this jasper (*i.e.* jade), "diamonds of the rock,"⁴ and azure (*i.e.* lapis-lazuli) were carried as presents by ambassadors from the West to the Emperor of China.

As stated in my *Economic Geology* (p. 517), the mines of

¹ New General Collection of Voyages and Travels. London: T. Astley. 1747. Vol. iv. p. 645.

² In the original, *Tusce*—a mistake, no doubt, for "*Yu she*."

³ By the Jesuits' map the river of Kotan runs about ninety miles east of Yarkand.

⁴ I am not quite clear as to the precise significance of this phrase, "diamonds of the rock," unless, perhaps, it is equivalent to "diamonds of the old mine," an expression apparently used for stones having crystalline forms, called *naifes* in India, as contrasted with "diamonds of the new mine," which were rounded pebbles.

Kotan are mentioned by Chinese authors who wrote 2000 years ago; and the system of dredging the rivers of that region for jade is known to have been in practice for many centuries. Other mines are situated at Karakash, in the Kuenlun range. These have been visited and described by several Europeans of late years.

Recently a rather general acceptance has been given to the view advocated at great length by Fischer, that the discovery of jade implements in Swiss lake dwellings is testimony of a prehistoric immigration of Asiatic tribes into Europe, as there is said to be now no known source of the material in Europe. This view has been, I understand, lately contested by Dr. Meyer, of Dresden, but I have not yet seen his work on the subject.

In the year 1609, De Boot published his famous work on precious stones. This, however, being merely a compilation as regards the information given about India, there is nothing in it which is not contained in the already quoted authors. It may also be added here, that the edition of De Boot's work, published by De Laet in 1847, only adds to his account facts derived from Methold.

JAHANGIR.—In the *Tuzuk-i-Jahangiri* (1616),¹ an account is given of diamond mines in the Chutia Nagpur, province of Bengal, which I have shown to be indentical with the Soumelpour, visited and described by Tavernier, as will be mentioned on a future page. There is no local tradition as to the precise site of these mines, which, therefore, remain to be rediscovered; but the search was certainly conducted in the bed of the Koel river.

METHOLD.—Our next authority is an English traveller named William Methold, whose account² of a visit to the diamond mines, made by himself and others, is entitled *Of the south-eastern parts, viz., Golchond, and other adjacent Kingdoms within the Bay of Bengala*. The visit appears to have been made between the years 1622 and 1626, the latter being the date of the publication.

The mines were situated 108 English miles from Masulipatam; they had only recently been discovered by the chance finding of a valuable stone by a goat-herd: when seen by Methold they gave

¹ Translated by Blochmann, *Jour. As. Soc. Bengal*: vol. xl. p. 113.

² Purchas's *Pilgrims*, vol. v. p. 1002. London: 1626.

occupation, according to native report, to 30,000 persons, a large proportion of whom were engaged in baling out the mines by hand—a tedious operation still practised in some parts of India. The mines were farmed out by the king for a sum of 300,000 pagodas, but he reserved to himself all stones of above 10 carats weight. In 1622 the mines were temporarily closed, owing to an ambassador from the Great Mogul having demanded a tribute of 3 lbs. weight of the finest diamonds. The locality was situated on the Kistna river, and was probably identical with the Gani or Coulour of Tavernier, the exact position of which has only recently been satisfactorily fixed as being identical with the modern Kollur.

LORD.—In the year 1630, a clergyman named Henry Lord, who was attached to the English establishment in Western India, published a curious pamphlet, entitled *The Discovery of the Banian (i.e. Brahmin) religion*. In it he gives an account of the Brahmins' ideas as to the first discovery of diamonds. It is attributed by them to the first progenitor of the Sudras or lowest caste of Hindus. Now the diamond miners throughout India, with rare exceptions, so far as I have been able to ascertain, still belong, and have always belonged, either to the Sudras or the aboriginal tribes, with whom they are much mixed up. This fact I hold to be of much importance in connexion with the explanation which I have offered of the origin of the diamond mining fable in connexion with the accounts of it given by Marco Polo and Nicolo Conte.

TAVERNIER (1665–1669).—In the accounts of his several journeys in India, Tavernier has given us a considerable amount of information, the value of which is, however, affected by the fact that these accounts contain a number of internal inconsistencies which it is impossible to reconcile with one another.

Diamonds.—Upon this subject the old jeweller naturally discourses at length: as, however, I have already quoted his facts in a former Paper,¹ I shall only here mention that the diamond mines at Raolconda, Gani or Colour, and Soumelpour have been identified by me² with the modern localities, Ramulkota, Kollur, and a spot on the Koel river in the district of Palamow in Bengal. Another

¹ These Proceedings, for 1880.

² *Economic Geology of India.*

locality which he mentions, namely, Gandikota, has also been identified.

If Tavernier's statements regarding the discovery and cutting of the Great Mogul diamond are to be relied upon, then that stone must have been distinct from the koh-i-nur. When writing of their probable identity, I overlooked the independent evidence which exists as to the koh-i-nur having been in the possession of the Mogul emperors long previous to the time when, according to Tavernier, they acquired the Great Mogul.

Gold.—In reference to this metal Tavernier says:—"Towards the Thibet, which is the ancient Caucasus, in the territories of a Raja beyond the Kingdom of Cashemir, there are three mountains close by one another, one of which produces excellent gold. . . ."

"There is gold also comes from the kingdom of Tipra (Tipperah on the borders of Assam); but it is coarse, almost as bad as that of China."

If gold washing or mining was carried on in any part of Peninsular India at the time of his visits, it is certainly remarkable that he should have been unaware of it, especially as he had heard of its being worked for in Thibet and Tipperah. Still I cannot but suppose that there were washings in some remote regions of which he knew nothing.

Silver and Tin.—"As for silver mines (he writes), there are none in all Asia, but only in Japan; but some years since at Delegora, Sangora, Bordelon, and Bata (localities in the Malayan countries), have been discovered plentiful mines of tin, to the great damage of the English, there being now enough in Asia of their own besides (*sic* in English translation).

The statement about silver is inconsistent with another made subsequently, that in Assam there were mines of both gold and silver.

Rubies, Sapphires, &c.—What Tavernier says on the subject of these stones shows that he was unaware of the existence of any source for them in Peninsular India. He says that they occur in only *two* places in all the east, and then forthwith mentions *three*. "The first is a mountain, twelve days' journey, or thereabouts, from Siren (*i.e.* Siriam), toward the north-east, the name whereof is Capelan. In this mine are found great quantities of rubies and espinels, or mothers of rubies, yellow topazes, blue and white

sapphires, jacinths, amethysts, and other stones of different colours.”

“The natives of the country call all coloured stones rubies, and distinguish them only by the colour: sapphires they call blue rubies; amethysts, violet rubies; topazes, yellow rubies; and so of other stones.”

The ruby mines are described in the *Economic Geology of India*, p. 427. They are situated about seventy miles north-east of Mandalay, the capital of Ava.

“The other place where rubies are found is a river in the Island of Ceylon. . . . The people make it their business to search among the sands for rubies, sapphires, and topazes. All the stones that are found in this river are generally fairer and clearer than those of Pegu.”

“Some rubies, but more Ballei's rubies, and an abundance of bastard rubies, sapphires, and topazes, are found in the mountains that run along from Pegu to the kingdom of Camboya.”

Whether by Camboya Tavernier meant Cambodia, beyond Siam, is uncertain; but he can scarcely have meant Cambay. He says that it is an error to suppose that emeralds are found in the East. Those exported from the Philippines to Europe were first brought thither by Spaniards from Peru.

In the above-quoted paragraph on gold in the region beyond Cashemir, the other two mountains he mentions produced “granats” (*i.e.* garnets), and “azure” (*i.e.* lapis-lazuli), respectively. This reference is, doubtless, to well-known mines of the spinel or Balas ruby, and lapis-lazuli, which are situated in Badakshan.¹

In 1673, a work was published on Asia by John Ogilby, which, as giving an epitome of the knowledge possessed in England of the mineral resources of India at that time, is not without interest. But some of the statements are not founded on fact. Thus, he says (p. 105): “The Ganges is supposed to abound with gold and pearls, and from its bottom are fetched all manner of precious stones, on some of which are represented the shapes of beasts, plants, and other things.” And again: “The Kingdoms of Golconda and Decan afford the inhabitants excellent diamonds. India also produces topazes, berils, rubies (which the Arabians call

¹ *Economic Geology of India*, pp. 429, 529.

yakut), hyacinths, granats, smaragds, chrysolites, amethysts, agats, Bezoar stones, and borax. Some places yield gold and silver and all manner of other metals."

Many of these minerals, it is believed, do not occur in India proper, and the term therefore is probably used in a very extended sense, and hence misconception has arisen no doubt. On page 157 he makes a remarkable statement, which might be used in support of the view contested in an early part of this Paper, namely, that India received *all* her gold from abroad. He says "Hindustan (by which, perhaps, only the realm of the Great Mogul is meant) possesses great quantities of gold and silver; but all is brought thither by strangers, never returning out again, for they melt down the European or foreign coins, and recoin them with the Mogul's stamp."

In a map, published by Wells in 1700, the positions of the diamond mines of Coulour and Raolconda are given with much greater accuracy than is the case in Rennell's map, published at the close of the eighteenth century. I was, however, confirmed in my conclusion as to the identification of the former by a manuscript map by Col. Colin MacKenzie, dated 1798, which is preserved in Calcutta.

In the maps of both Ogilby and Wells, Narsinga, a place often mentioned in the early accounts, is indicated as being situated to the east of Bisnagar (*i.e.* Vijayanagar).

HAMILTON.—Captain Hamilton, who traded in the East Indies between the years 1688 and 1728, is our next authority.¹ He informs us that iron was made into anchors at Balasore, apparently by European methods: if so, this was the first manufacture of that kind in India of which there is any record. He quotes a curious story as to mercury having been brought to Achin in Sumatra from the Andaman Islands by a native, who, having been held for some time as a slave, was allowed to revisit his country on several occasions, and after each returned with some mercury which, he stated, was obtainable there (*i.e.* probably in the Little Andaman). This statement, together with a consideration of the geological structure, has led me to suggest the possibility of a future discovery of the metal in the islands of the Andaman group. In age and in characters

¹ New Account of the East Indies, vol. i., chap. xxix. Maderas or Chinapatam.

there appear to be several points of resemblance between some of the Andaman rocks and those which contain the valuable mercury mines of California.

“The diamond mines, being but a week's journey from Fort St. George, make them pretty plentiful there; but few great stones are now brought to market there, since that great diamond which Governor Pitt sent to England. How he purchased it, Mr. Glover, by whose means it was brought to the governor, could give the best account, for he declared to me that he lost 3000 pagodoes by introducing the seller to Mr. Pitt, having left so much money in Arcat as security, that if the stone was not fairly bought at Fort St. George, the owner should have free liberty to carry it where he pleased for a market; but neither the owner nor Mr. Glover were pleased with the governor's transactions in that affair.”¹

“Some customs and laws at the mines are: when a person goes thither on that affair he chooses a piece of ground, and acquaints one of the king's officers, who stay there for that service, that he wants so many *covets* of ground to dig in; but whether they agree for so much, or if the price be certain, I know not. However, when the money is paid the space of ground is inclosed, and some sentinels placed round it. The king challenges all stones that are found above a certain weight—I think it is about 60 grains; and if any stones be carried clandestinely away above the stipulated weight, the person guilty of the theft is punished with death. Some are fortunate, and get estates by digging, while others lose both their money and labour.”

The remaining two authorities among those Europeans who personally visited the mines they describe were, Mustapha,² a Turk, who traversed the diamond-bearing region of Chutia Nagpur in 1758, and Motte,³ who was deputed by Lord Clive in 1766 to purchase diamonds at Sambulpur, on the Mahanadi. The facts they record are chiefly of interest as proving the existence of the industry at those periods, and need not be further dwelt upon here.

¹ A different version of the transaction by Mr. Pitt himself was published after his death.

² *Oriental Repertory*, vol. ii. p. 261. London: 1808.

³ *Asiatic Annual Register*. London: 1799.

In recapitulation of the conclusions which I have been led to as the result of this analysis of the facts recorded by the above-quoted writers, the following may be enumerated:—

First. The great antiquity of the knowledge possessed by the natives of India with reference to certain metallurgical processes, is, I think, fairly established. The most notable of these is, undoubtedly, that by which *wootz* or cast steel was manufactured. Probably the method of refining gold which is mentioned in the *Ain-i-Akbari* is also very old; but we have no earlier record of it. I question the accuracy of a statement made by Strabo, or at least its applicability, even in his time, to the whole of India, where he says, “The Indians, unacquainted with mining and smelting, are ignorant of their own wealth.”

Second. Many ancient, long-forgotten mines, the names of which, only, have survived in more or less archaic garbs, have, by the methods here adopted, been identified with modern sites. In most of these cases geological evidence has established these conclusions, and in some instances they have been further ratified by local traditions acquired as the result of personal inquiries.

Third. Several fables of world-wide notoriety have been shown to have had their origin in *facts* connected with customs which were formerly little understood, but, being still in practice, are now susceptible of close examination and explanation.

Speaking generally, I venture to believe that I have in this Paper placed within the reach of historians a number of facts that serve to elucidate several subjects hitherto manifestly puzzling to those unacquainted with the results which have been arrived at by the systematic examination of the Geology of India.

XV.—REPORT ON THE FLORA OF THE WEXFORD AND WATERFORD COASTS. BY H. C. HART, B.A.

[Read, May 21, 1883.]

ON the evening of the 27th of July I reached Wexford, and on the following morning took boat across the harbour to Rosslare Point. This is the northern extremity of a long spit of sand between the harbour and the sea, and here commences the Wexford coast-line south of the harbour. In 1881 I had examined the coast-line northwards to Arklow, starting at Raven Point, which lies opposite to Rosslare on the north; and my explorations there, connected with those I am about to describe, include the entire coast-line of Wexford and Waterford, with the exception of the muddy shores of the larger estuaries, which I usually left untouched. These are chiefly occupied by towns, and easy of access, and have, no doubt, been frequently examined. I also spent a day upon the Saltee Islands, off the south coast of Wexford, where I made some interesting discoveries, and a list of the plants. In this summary of the distribution of plants on the south-eastern shores of Ireland I shall make use of a previous Paper of mine on the subject.¹ My observations of the spring plants are but scanty, depending on a walk from Courtown to Wicklow in May of the present year (1883).

July 28. At the extremity of Rosslare Point is a pilot tower and a coastguard station. In the neighbourhood of these I found *Lycium barbarum* and *Anchusa officinalis*, both apparently established. The latter I have not seen recorded nor met with in Ireland before: the former is thoroughly naturalized in several places on the east coast. Here also I noticed *Echium vulgare*, *Ballota nigra*, and *Elymus arenarius*, probably introduced also. I have doubts about *Elymus arenarius* being a native species on the Wexford coast, which will be dealt with subsequently. In this locality it does not occur off the cultivated patches of land, and has not even spread over the surrounding sand-hills. The native sand-hill species at the ex-

¹ See Journal of Botany, November, 1881.

treme point were: *Eryngium maritimum*, *Cakile maritima*, *Arenaria peploides*, *Euphorbia paralias*, *Viola curtisii*, *Carduus pycnocephalus*, *Senecio jacobæa*, var. *flosculosus*, *Convolvulus soldanella*, *Salsola kali*, *Cynoglossum officinale*, and other commoner species. About a quarter of a mile southwards I gathered *Trifolium arvense*, *Apargia hispida*, and *Festuca uniglumis*; these were chiefly on the harbour side of the spit of sand. *Lavatera arborea* and *Hyoscyamus niger* were also seen near the station; the former not native, the latter very uncertain, and casual in its appearance. About half a mile from the point *Juncus acutus* first appears, and at a mile down it is abundant on the harbour side. The outer shore is here a complete waste of shifting sand. On the harbour side I also noticed *Phleum arenarium*, *Erythræa pulchella*, *Carlina vulgaris*, *Ænanthe lachenalii*, *Carex distans*, and *Carex extensa*. The latter was growing in a remarkable manner, erect amongst the tussocks of *Juncus acutus* to a height of 18 or 20 inches. *Erythræa pulchella* is a rare species, which has not, I think, been gathered south of Curracloa, in Ireland previously. Here also I noticed abundance of *Erodium maritimum* and *Chlora perfoliata* in fields where the neck of land has widened. On this light sandy soil the most prominent species, especially on the ditch-banks, were *Salix repens*, *Lychnis vespertina*, *Filago germanica*, and *Filago minima*. I gathered here a curious-looking *Filago*, which at the time I thought might have been a hybrid between these two species; but I unfortunately lost the specimen. *Vicia angustifolia* is also frequent here. Here again was a small quantity of *Elymus arenarius*, this time on ditch-banks of a potato garden close to a cottage. About three miles from the point are higher sand-hills, and amongst these, east of Rosslare House, I observed *Solanum nigrum*, *Chenopodium rubrum*, *Agrimonia eupatorium*, *Pastinaca sativa*, *Reseda luteola*, *Ballota nigra*, *Anthemis cotula*, and others already mentioned. *Solanum nigrum* is a very rare plant in Ireland, for which I was glad to find a new locality. *Pastinaca sativa* wears the appearance of a native here, but is probably introduced. In ditches near this I gathered *Equisetum maximum*. Here there is a small village on the shore, and at this point *Juncus acutus* disappeared for the present: *Erodium maritimum* is still common.

Having left Rosslare, the coast becomes a steep, low bank for about two miles to Greenore Point, similar to the marl banks north

of Curracloa to Blackwater. Along here *Sinapis nigra* is very frequent, and, I should say, undoubtedly native; as such it is very rare in Ireland. Along these banks, where the coast sweeps round eastwards, about half way between Rosslare and Greenore, I gathered *Helminthia echioides*, *Linum angustifolium*, and *Convolvulus arvensis*. On the north side of Greenore Point a small patch of *Elymus arenarius* occurs in a less suspicious-looking locality than the others. Here, too, I gathered *Carex vulpina*, *Senebiera coronopus*, and *Stachys arvensis*, and at the point *Festuca arundinacea* and *Polygonum raii*. A little south of Greenore, *Erodium moschatum* and *Crithmum maritimum* occur—the former in doubtfully native circumstances. Along this coast *Inula dysenterica* is a characteristic plant, being remarkably abundant. From Greenore Point to Carnsore Point, or “Carn,” as it is called in the neighbourhood, the coast is low, and at first sand-hills with a beach of porphyry, then red granite. A little south of Greenore I first met with *Salvia verbenaca*, on the Wexford coast. It occurred again nearer to Carn, and I noted, too, *Poa rigida*, *P. loliacea*, *Cerastium semidecandrum*, *Cynoglossum officinale*, *Beta maritima*, and *Glaucium luteum*, on the coast at St. Margaret’s. At Nethertown, *Artemisia absinthium*, afterwards frequent, was first met with. It never occurs on the wilder part of the coast, or far from cultivation, and is, no doubt, introduced. Here, too, I gathered *Apium graveolens*. It was now dusk, and time to look for accommodation for the night. With some difficulty I obtained a bed at the post-office at Churchtown. I may mention, lest it should be thought the ways of botanists are those of unmixed recreation, that my fare for this tour was of a most meagre description, and, with very few exceptions, I should have preferred to pass the night on foot rather than in the only places I could find to sleep. However, the people did their best, and the lobsters, the staple article of diet, were excellent.

July 29. About Churchtown I observed *Apium graveolens*, *Erodium moschatum*, *Lamium incisum*, *Œnanthe crocata*, and *Cynoglossum officinale*; and at the shore at Carn, *Convolvulus soldanella*, *Erodium maritimum*, and *Euphorbia paralias* were abundant. I was now fairly round the south-east corner of Ireland. The Saltee Islands were in view before me. This part of the coast is extremely lonely and desolate. For a mile or so, sand-hills bordering the sea on one side, and a tract of sheep pasture inland, yielded nothing

fresh. I now reached the narrow bank of sand which separates Lady's Island Lake from the sea, a lake abounding in ducks, black-headed gulls, and other wild-fowl. This lake has no outlet, and as it is of considerable size, about ten miles in circumference, and receives much drainage and many small streams, it causes occasionally most injurious floods. When these become past endurance, the inhabitants of the country round assemble, and in a few days succeed in cutting a channel through the sand to the "big sea." This is soon again filled up: when I was there it had not been open for two years, and the flood was then considerable. The plants of this lake betray its brackish tendency. Such unusual conditions were not to be passed over, and I determined to make a complete circuit of the lake. On the bar at the eastern side of the lake on the sea-margin I found *Diotis maritima*, the sea cottonweed, one of the rarest Irish plants, very beautiful with its snow-white woolly foliage, and conspicuous at a considerable distance. It grows on the barest sandy shores with scattered plants of bent, sea bindweed, and sea spurge. A barren gap occurs, the part where the channel is at times cut through, and then in a few hundred yards *Diotis* occurs again abundantly on the margin of the lake at its seaward end, and along the coast for about a mile to the bar of Tacumshin Lake, another brackish inlet. This plant is found at one place on the Kerry coast, and another in Waterford, Ballyheigh, and Tramore respectively. In England, according to Watson, it is now nearly extinct on the south-western shores. It was first recorded from the present site by Mr. John Waddy, and has since, I believe, been more accurately traced by Mr. Kinahan. On the coast below Lady's Island Lake I also gathered *Raphanus maritimus*. On the eastern margin of the lake the following plants were noticed in the order mentioned:—*Ænanthe lachenalii*, *Potamogeton pectinatus*, *Zannichellia palustris*, *Ranunculus baudotii*, *Bidens cernua*, *Rumex hydrolapathum*, *Lycopus europæus*, *Carex ovalis*, *C. hirta*, *C. extensa*, and other commoner sedges and marsh species, to about the middle of the eastward shores of the lake, half a mile from a village. Here I discovered *Rumex maritimus* sparingly, but afterwards plentiful, especially on the northern shore abreast of Lady's Island. This is an important new habitat. *R. maritimus* grows abundantly at a long-known station, that of Garristown bog in Dublin, where I observed it immediately after the tour I am now describing.

Elsewhere in Ireland it is only known sparingly from Kilcoleman bog in Cork. Continuing my notes, I met with *Apium graveolens*, *Scirpus savi*, *Chenopodium rubrum*, and *Rumex hydrolapathum*. The latter is abundant in many places, especially in neighbouring swamps on the west side of the lake. About Lady's Island I noticed *Artemisia absinthium* thoroughly established, *Anthriscus vulgaris* amongst the ruins on the island, *Parietaria officinalis*, *Equisetum maximum*, *Ænanthe crocata*, *Lepidium smithii*, *Lycopus europæus* very abundant, and *Anthemis nobilis*. *Saponaria officinalis* is also established here. At Lady's Island I found a "boycotted" publican; here I rested for an hour, and heard his side of the "burning question." I then made my way by the shores of the lake to the sea coast, almost to the point I left. I have already mentioned the distribution of *Diotis maritima*. Here the walking became very laborious, in soft, heavy sand, along the narrow strip between Tacumshin and the sea. The plants I noticed, rapidly diminishing, were: *Glaucium luteum*, *Atriplex littoralis*, *Raphanus maritimus*, and *Polygonum aviculare*, var. *littoralis*, forming mats three feet long. After a while I was alone on a sandy waste, a high bank of shingle and sand forming a bar between the lake and the sea. I had gone a little way round the shore of this lake at first inland, but it was low, flat, and muddy, and the long strip of sandy coast looked more promising. What was my horror, after about two hours' wearisome labour, to find a swift blue torrent, over a hundred yards across, foaming out of the lake into the surge of the sea. It was out of the question to go back. I would have lost a whole day by doing so, and nothing would have induced me to face that sandy trudge again. There was neither boat nor human being in sight. I felt evilly disposed towards several persons who knew where I was bound for, and had not intelligence enough to warn me, and especially towards the Ordnance Map, which is quite out of date for this changeable coast. On the map is marked a channel from Lady's Island Lake, and a continuous coast outside Tacumshin. The reverse is the true state of things. With some misgivings, I resolved to swim. This necessitated three journeys: one with my knapsack, which I emptied on the opposite side; one back with it empty, and a third with my clothes, boots, &c., in the knapsack. The knapsack floated bravely, and I towed it with a strap in my teeth. Each time I started about forty or fifty yards higher up

the current than the point opposite; but the third time, whether I was tired, or the knapsack was very much heavier, I was carried well into the strength of the current at the bar, and began to wonder how far it was to Cardigan Bay. However, I accomplished the transport and resumed the journey. A few miles more brought me to a clean little inn at Kilmore. On the way I noticed *Erodium maritimum* and *Atriplex littoralis*. Through the courtesy of the chief boatman at the Coastguard Station I was able to make arrangements that night for a day on the Saltee Islands, of whose botany I had seen no report.

July 30. A tolerably early start in the Coastguards' boat, manned by four able men, brought me in about an hour to the great Saltee Island, which lies south of Kilmore, and about four miles distant. The lesser island, about half the size of the greater, is a mile and a-half nearer shore. It is a third of a mile in width, and three-quarters in length. Greater Saltee is, roughly speaking, the same width and twice that length. A line drawn north-east and south-west would, approximately, form the greater axis of both islands. They are composed chiefly of gneiss and other hard metamorphic or Cambrian rocks. I met with no limestone. Considering their small size, the flora is varied, and some very interesting varieties occurred. There are no shrubs or trees. On the larger island *Linaria elatine* was gathered on the shingly shore below cultivated fields, about half a mile south of the landing-place. This plant has been found previously in very few localities, chiefly in the county Cork. At the south-western extremity of this island I was pleased to meet with *Radiola millegrana*, very rare in the south-east of Ireland, and not gathered in this district before. *Chenopodium rubrum* occurs here, indisputably native, in characteristic abundance. It may be seen in quantity amongst the rabbit-holes and rocky ground at the barren south-eastern corner of the island. This plant is very rare and local in Ireland, and chiefly occurs on the Wexford coast; nowhere, however, so commonly as in the present situation. *Inula crithmoides* is also a characteristic plant, occurring in several places, always on the east side of the island. This has not been noticed along the Irish coast in this district before, its nearest recorded stations being Howth on the north, and Ardmore on the west. A few other interesting plants were noticed: *Stachys arvensis* and *Anthemis cotula* are very fre-

quent in the corn fields. *Crithmum maritimum*, *Beta maritima*, *Erodium maritimum*, *Lanium amplexicaule*, *Hypericum elodes*, and *Euphorbia paralias* were also observed. On the smaller island, *Enanthe crocata*, *Equisetum maximum*, and *Tussilago petasites* occur, which were not noticed on the greater Saltee. On the two islands a hundred and fifty-two species were observed, about a dozen of which, perhaps, are introduced. Of these a detailed list is appended. A few more, no doubt, occur, for whose observation another visit would be requisite.

A list of the species observed on the two islands will be appended to this Report. The great island is a home for breeding sea-fowl, chiefly puffins, which resort here in astonishing numbers. At the south-western corner of the island the ground by the edge of the cliffs and near them is trodden as bare as asphalt, and riddled with holes for a considerable area by this species. I observed rock-pigeons, oyster-catchers, herring-gulls, lesser black-backed gulls, guillemots, razor-bills, shags, and kittewakes. I was informed by the farmer in charge of the island that ravens, peregrines, greater black-backed gulls, and a few pair of sheldrakes also breed annually. At the time of my visit the birds had for the most part left the island, but a very considerable number still remained with their young. The birds are not allowed to be molested. On this island, which is partly cultivated, there is a resident family. The lesser Saltee is used as pasturage, and contains but one cabin for the occasional use of herd-boys.

July 31. I left Kilmore early, and after rounding Crossfar-noge Point there lay before me a long stretch of sandy coast forming Ballyteigue Bay, and beyond, the low rocky shore stretching south to Hook Head. On the inside of the sand-hills a parallel dyke has been cut for drainage from brackish overflows and salt lakes. This reaches about three miles, and I examined it as well as the barren coast outside, continually crossing and zigzagging backwards and forwards. The plants met with were: *Erodium maritimum*, *Viola canina* (Linn.), *Convolvulus soldanella*, *Carlina vulgaris*, and in the canal, *Zannichellia palustris*, *Potamogeton pectinatus*, *Carex vulpina*, *Myriophyllum spicatum*, *Scirpus tabernæmontani*, and others. On the sandy ground, about two miles from the point, *Ononis arvensis*, *Senecio jacobæa*, var. *flosculosus*, and *Euphor-*

bia portlandica were gathered. The latter is much rarer than *E. paralias* along the Wexford shore. On these sand-hills, *Rosa pimpinellifolia* is the most abundant plant; *Rubus cæsius* also occurs. About a mile east of the Coastguard Station, and about five miles west of Crossfarnoge Point, I first met with the rare *Asparagus officinalis*. This is probably the locality recorded by Mr. Lewis in Mr. More's recent addition to the Flora of Ireland. It occurs here sparingly, perfectly prostrate, and would easily be overlooked. Further on I found it at the sandy spit outside the salt water lough abreast of the Coastguard Station. Here also I gathered *Hyoscyamus niger*, *Glaucium luteum*, *Lycopsis arvensis*, *Chenopodium rubrum*, *Carduus pycnocephalus*, *Solanum nigrum*, *Viola canina*, *Beta maritima*, *Erodium maritimum*, and *E. cicutarium*. Of these, the Henbane was very plentiful, and *Solanum nigrum* occurred in some quantity.

Here I hailed the coastguards, and got ferried across the "Bar of the Lough"; the only name I could learn for this interesting locality. The botany of this remote neighbourhood would, I imagine, well repay further research. Near this, *Lythrum hyssopifolium* has been discovered in its only Irish locality. I searched for it along the banks and swamps of a small stream, a little east of Ballymadder, which is, I believe, the reported station, but without success. It is a very rare and uncertainly distributed plant. Along this stream, *Rumex hydrolapathum* and *Carex acuta* grow plentifully. Close to it were seen *Malva moschata*, *Apium graveolens*, and *Senebiera coronopus*. Along the coast here, and on Bannow Island, *Convolvulus arvensis* is a common species. The eastern channel to Bannow Island is silted dry, or nearly so, with sand. On Bannow I gathered *Centaurea scabiosa*, *Apargia hispida*, *Hyoscyamus niger*, *Torilis nodosa*, and others; and on bluffs along the seaward face, *Asparagus officinalis*, a new locality for this very rare species already mentioned. It was blowing a gale of wind, and there was much difficulty in inducing an aged couple to ferry me across the estuary. This voyage accomplished, in the frailest of crafts, I made my way to Fethard. On the way I noticed *Stachys arvensis*, *Pastinaca sativa*, *Centaurea scabiosa*, and *Origanum vulgare*. I reached Fethard at about four in the afternoon, and having arranged for accommodation for the night, I determined

to cut off a piece of my next day's walk round Hook Head, which looked somewhat alarming. About Fethard I gathered *Scandix pecten-veneris*, *Tanacetum vulgare*, *Lychnis githago*, *Apium graveolens*, *Juncus glaucus*, and *Ænanthe crocata*. South of Fethard, by the roadside, *Chenopodium bonus-henricus* occurs. Along the coast, which is here of low slabs and schistose cliffs to Baginbun Head, I gathered *Sarothamnus scoparius*, *Crithmum maritimum*, *Atriplex angustifolia*, *Statice occidentalis*, *Chlora perfoliata*, *Eupatorium cannabinum*, *Epilobium hirsutum*, and *Equisetum maximum*. *Statice occidentalis* has not been previously gathered nearer than Arklow in Wicklow to the north, and Tramore in Waterford to the west. At Baginbun Head, *Inula crithmoides* occurs with *Statice occidentalis* again. The promontory of Hook appears to have never been visited by a botanist. A little south of Baginbun, *Ulex europæus* and *Ulex nana*, both decorate the coast, the latter being henceforward a prominent coast species. On dry banks along here I found *Senebiera didyma*, afterwards a prevalent species. From Carnivan Head I returned by road to Fethard.

On the 1st of August, I took up the coast again at Carnivan Head. The cliffs are now somewhat steeper, 50 to 100 feet in height, of a red horizontally-stratified sandstone and conglomerate. Along here, choughs and rock-pigeons were met with; of the former, perhaps, their most eastern locality in Ireland, except in the north. On the margin of these cliffs, on grassy banks a little south of Carnivan, I gathered *Trifolium scabrum* in an intermediate station between Youghal and Wicklow, its nearest previously-known habitats. A very glaucous form of *Dactylis glomerata*, which I have gathered on Mweelrea, in Mayo, grows here plentifully. About Sandeel Bay, I first met with *Rubia peregrina*, afterwards becoming frequent. Howth, in Dublin, and Tramore, were its nearest known stations. *Euphorbia exigua* and *Hyoscyamus niger* were noticed along Sandeel Bar. Here the sandstone conglomerate is overlaid by a highly fossiliferous carboniferous limestone. *Polygonum raii* grows along here commonly to Patrick's Bay; and nearer to Churchtown, *Inula crithmoides* and *Statice occidentalis* again appear. The former is very plentiful on the low rocky coast, right round the long, narrow point of Hook, and at the very point *Statice occidentalis* is abundant.

The scenery along here is delightful, and one obtains an extensive prospect of coast and sea at the point of Hook. There is a feeling of remoteness and loneliness about this oddly-left streak of rocks which one hardly expected to find in the county of Wexford, and which is rather heightened by that monstrous uninhabited palace, Loftus Hall—an edifice which the natives maintain is “the largest in the kingdom, except one in London”; and, judging from appearance, they may not be far astray. For four miles this point is about half or three-quarters of a mile in width, utterly exposed, and unable to produce timber except the lowest scrub. The soil is of the poorest description, and harbourage for boats there is none. A few cottagers and fishermen exist, and here stands the largest palace but one in the kingdom! I heard it had been once visited, but never inhabited, by its owner. About Churchtown *Senebiera didyma* was again observed, and along the coast *S. coronopus* formed the sward in many places. At the Point *Crithmum maritimum* and *Aster tripolium* abound. Near a limekiln, on the water side of the Point, I gathered *Atriplex littoralis*, *Erodium maritimum*, and *Cochlearia danica*. About half a mile north of the lighthouse, *Inula crithmoides* ceases to grow. *Statice occidentalis* was not seen past the Point. About a mile and a-half north of the Point, immediately below Loftus Hall on the west side, I found a single patch of *Trifolium fragiferum*. This is the only place I met with this species in the county, and there must be some mistake in the record in the “Recent Additions,” “common near the sea, in Wexford.” Perhaps it should stand near the town of Wexford? It may occur in the Waterford or Wexford estuaries, which I hardly botanized, but is certainly not common. A few miles further brought me well into the Waterford estuary, and I found no plants of interest. On the supposition that I was nearing a large town, and in places easy of access and well explored, I abandoned the coast from Duncannon to Tramore. Along the roadside, a little south of Duncannon, I noticed *Helminthia echioides*, *Chlora perfoliata* and *Juncus glaucus*; and at Duncannon *Salvia verbenaca*, *Dipsacus sylvestris*, *Pastinaca sativa*, and *Senebiera didyma*. This is a second locality for *Helminthia echioides*, a rare plant not previously noticed in the district.

Having crossed the estuary from Ballyhack to Passage by

ferry-boat, I was out of District 4 and into District 2 of the "Cybele Hibernica." At Passage I observed *Artemisia absinthium* and *Centranthus ruber*, the latter an ornament to the rocks. Between Passage and Waterford, which I travelled by mail car, I observed *Scrophularia aquatica*, common in many places in Waterford, but a locally-distributed plant.

August 2. Along the railway between Waterford and Tramore *Malva moschata* and *Equisetum maximum* were noticed. The sand-hills east of Tramore are a known habitat for *Juncus acutus* and *Diotis maritima*. I started westwards along the cliffs south-west of Tramore, keeping continually in mind, as I had done since I left Wexford, that it was necessary to examine all stony beaches for *Euphorbia peplis*, which has appeared occasionally on this coast. Moreover, *Erica vagans* has been stated to occur on the cliffs west of Tramore. Along the cliffs immediately west of Tramore I noticed *Rubia peregrina*, *Inula crithmoides*, *Statice occidentalis*, and *Crithmum maritimum*, to Newtown Head or "The Metal Man." On the cliffs beyond Newtown Head I met with *Lavatera arborea* in a thoroughly wild station. *Inula crithmoides* and *Rubia peregrina* are very frequent along here: *Lavatera arborea* and *Statice occidentalis* occur more sparingly. Here I came to the first accessible beach, a little on the Tramore side of Garraris Cove, the locality in which *Euphorbia peplis* has been discovered. On this beach I was struck with the strong resemblance which young leaf-shoots of *Glaucium luteum* bear to those of *Diotis maritima*: the latter, which was fresh in my memory, is somewhat whiter. For some distance I kept the base of the cliffs in search of *Euphorbia peplis* but without success. It will suffice to say that I examined every beach from Tramore to Youghal more or less carefully, especially those between Tramore and Dungarvan, and was much disappointed to find no trace of this very rare and uncertain species. I questioned fishermen, boatmen, cockle-gatherers, and dulse and carrigeen women, in many nooks and corners. It was easy to learn from these accommodating Celts that the plant was usually abundant: milky juice, red foliage, and all peculiarities unmistakably described—after they were informed of them. One woman in Garraris Bay assured me she knew it, but that like everything else along the shore it was "tore out of it" by the

terrible storms of September and October, 1881. Perhaps she was right, since the plant grows on the margin of the tide. The trudging for miles along the heavy shingly shore at the base of the limestone cliffs, between Kilfarrasy Island and Annestown was a thing never to be forgotten. On the other hand, the first few miles along the cliffs south of Tramore is as thoroughly enjoyable a sea-coast walk as one could wish to repeat. At Kilfarrasy Island I gathered *Trifolium arvense*, a very thinly-distributed species in its native stations, but one which increases quickly on light sandy cultivated soil near the sea. Here it occurred sparingly on steep banks. On the sheer limestone cliffs just mentioned *Raphanus maritimus* is a very characteristic species. I have not seen it so satisfactorily a member of the flora in any other district. At Annestown, a small and very prettily-situated group of cottages, I was hospitably entertained at lunch by Mrs. Palliser, wife of Major Palliser, the owner of the soil, who saw me from their dwelling-house near by, searching the village for refreshment, and, with thoroughly appreciated kindness, invited me in. Along banks above the sea, at Dunabrattin Bay and about Annestown, *Senebiera didyma* looks wild enough. *Inula crithmoides* and *Rubia peregrina* both occur at Dunabrattin Head, and here again I met with the chough. About half way between Annestown and Knockmahon *Statice occidentalis* and *Raphanus maritimus* were again observed, the latter abundantly. The rock is chiefly a slaty limestone, and nearer to Bunmahon, where mining operations to a great extent were formerly carried on, gives place to red hematite, &c. Near the shore here, in a swamp, I gathered *Ænanthe fistulosa*, a plant I seldom meet with, though said to be frequent. At Bunmahon, a melancholy wreck of deserted cottages, heaps of rubbish, disused rails, mining shoots and properties of all kinds, I found a remarkably spinous form of *Ononis arvensis*, large and erect, and readily liable to be mistaken for *O. campestris*. A little beyond Bunmahon *Rubia peregrina* is very abundant.

August 3. Beyond Bunmahon the coast is precipitous, and beautifully diversified with bays, stacks, and pinnacled islets. The cliffs here are for the most part sheer, 200 to 300 feet in height. The rock is at first a dark slaty rock, and then red conglomerate, probably of the Old Red Sandstone formation. These cliffs are

inhabited by the peregrine falcon. Their margins are gay with Scotch heather, dwarf furze, lady's finger, sea pink, and campion. *Gentiana campestris* was noticed as being very large. The travelling here was very laborious, and the weather had become oppressively hot. Headland and inlet in succession made the coast line beautiful no doubt, but very difficult to examine. At Ballydowane Bay I gathered *Rubia peregrina*, *Trifolium arvense*; and a little west of it, by a small stream, *Osmunda regalis* and *Habenaria viridis*: nearer to Stradbally, *Equisetum maximum* and *Artemisia absinthium* were noted. On the cliffs west of the inlet below Stradbally, *Ligustrum vulgare* is abundant in perfectly native situations. It would, I believe, be hypercriticism to challenge the privet's claim to a place in the native flora of Ireland. It extends along the coast here for about half a mile, commencing a quarter of a mile west of the Stradbally inlet, and appears again in many places to Ballyvoyle Head. It grows in a semi-prostrate tangled form on the steepest and most inaccessible parts of the cliffs, where there are patches of soil. I have not seen privet native elsewhere in Ireland except at Howth, but Dr. Wright found it under similar conditions nearer to Tramore. At the Stradbally inlet I saw *Orobanche hederæ* and *Carlina vulgaris*. With the privet, *Rubia peregrina* has become very abundant along the coast to Ballyvoyle Head. *Raphanus maritimus* and *Inula crithmoides* still occur. By a small stream a little east of Ballyvoyle Head, I noticed *Lepidium smithii*, *Lycopus europæus*, *Agrimonia eupatorium*, *Carex remota*, and *Eupatorium cannabinum*. On Ballyvoyle Head, east side, *Vicia sylvatica* grows abundantly; on the west side, towards Ballyvoyle Bridge, *Senebiera didyma*, *Carduus pycnocephalus*, and *Artemisia absinthium* are plentiful. I had now reached the lowlands again, and was well pleased to see a considerable marsh between me and Dungarvan, which would afford at once rest and variety. I found the flora of this marsh very interesting; it is a small murrough, similar to that at Kilcoole, on the coast of Wicklow, but less extensive. It lies in the parish of Clonea, inland and eastward from Clonea castle. It does not appear to have been examined by a botanist previously to my visit. On the seaward edge I noticed *Oenanthe lachenalii* and *Carex vulpina*. In

heavy dykes and on their banks occurred *Ruppia maritima*, *Scirpus tabernæmontani*, *Carex acuta*, *Rumex hydrolapathum*, *Potamogeton pectinatus*, *P. pusillus*, *Juncus glaucus*, *Lycopus europæus*, *Typha latifolia*, *Utricularia vulgaris*, *Alisma ranunculoides*, *Poa aquatica*, *Ranunculus lingua*, *Myriophyllum verticillatum*, *Sium angustifolium*, *Carex remota*, *C. stricta*, and *C. paniculata*. Of this interesting assemblage of plants, some of which are very rare, the only record I find in the "Cybele" is that of *Rumex hydrolapathum*, noticed at Clonee by Wade. At the shore at Clonea may be seen *Glaucium luteum*, *Polygonum raii*, *Convolvulus arvensis*, and *Senebiera didyma*. This latter species has as much claim, or I should be inclined to say, even more claim to be regarded as native than *Senebiera coronopus* on the south coast of Ireland, so far as external appearances go. Further south I met with nothing of interest till I reached the lighthouse. Between that and the Coastguard Station, *Helminthia echioides* occurs, and here, as elsewhere, through the day, the prevalence of *Geranium dissectum* was noted. It is probably native in this part of Ireland. From this I obtained a boat across the harbour to Dungarvan, the dirtiest and most disreputable-looking town in Ireland.

August 4. Having taken a boat for Helvick Head, five miles off, the outer and southern point of the harbour, I left Dungarvan early. On the way I landed at the Cunnigar, a long spit of sand stretching up from the southern side to the northward. *Juncus acutus*, *Polygonum raii*, and *Artemisia absinthium*, were observed: the rush has previously been noticed here. At Helvick Head, where the coast becomes steep and mountainous in character, I met with *Inula crithmoides* and *Trifolium arvense*, as also some upland species, *Solidago virgaurea* and *Molinia cærulea*. A mile southward, *Osmunda regalis* and *Senecio sylvaticus* were noticed, and *Rubia peregrina* is frequent along this coast. *Equisetum maximum* and *Carduus pycnocephalus* are also frequent. *Inula crithmoides* was met with all along to Ardmore. At Mime Head (a great resort for cormorants) *Trifolium arvense* occurs again; and *Torilis nodosa*, a rare species, is very frequent. Foxglove and oak occur along these steep headlands in profusion, the latter in its stunted native form. *Beta maritima* is also a prevalent plant; at Mime Head, too, I found a steep bank decorated throughout with

the very local and handsome species *Vicia sylvatica*. At Ballyernan, a few miles north of Ardmore, I found *Linum angustifolium*, *Juncus glaucus*, *Lychnis githago*, *Pastinaca sativa*, *Anthemis cotula*, and *Centaurea scabiosa*. Close to Ardmore, *Salvia verbenaca* and *Scandix pecten-veneris* were also met with. It was late when I reached the prettily-situated village of Ardmore. The day had been a roasting one, and the walking unusually severe, so that the most primitively conducted inn I have yet discovered was a welcome object. Here I remained for the night.

August 5. Ardmore Head, to the south of the village, is most picturesque and enjoyable. An early start brought me round the head and along the coast into Youghal by the ferry by two o'clock. Ardmore Head has been frequently botanized, and is rich in variety as well as rarities. I observed *Solidago virgaurea*, *Artemisia absinthium*, *Rubia peregrina*, *Vicia angustifolia*, *Centaurea scabiosa*, *Inula crithmoides*, *Cichorium intybus*, *Trifolium arvense*, and others of less interest. West of Whiting Bay, *Juncus glaucus* and *Apium graveolens* were noted; and on the headland between that and Youghal Harbour at a small strand, I observed *Glaucium luteum*, *Euphorbia paralias*, *Linum angustifolium*; and a little farther, *Filago germanica*, *Echium vulgare*, *Verbena officinalis*, *Verbas-cum thapsus*, *Rubia peregrina* and *Inula crithmoides*. Opposite Youghal occur *Fœniculum vulgare* and *Calamintha officinalis*, and, as in many other places previously, horse-radish has here established itself. *Verbena officinalis* and *Calamintha officinalis* are distinctly southern plants in Ireland, and are known to occur in many Cork stations, at which county I had now arrived. This county has been well explored by numerous botanists; and here I left the coast, and took a passage on the steamer up the Blackwater, to Cappoquin, and thence to Dublin.

In the appended systematically-arranged list of my observations, I have included localities noticed in the spring of the present year between Courtown and Arklow, as well as those already referred to in a Paper of mine in the "Journal of Botany." The plants enumerated are brought together to display the species which prefer the margin of the sea, as well as new localities for the rarer sorts; and, for facility of reference, I have included all the less common species observed.

The following are additions to the Flora of the Districts in which they occur, as given in the "Cybele Hibernica" and its supplement:—

- Sinapis nigra* (Linn.)—District 4.
Raphanus maritimus (Sm.)—District 2.
Lavatera arborea (Sm.)—District 4.
Radiola millegrana (Sm.)—District 4.
Rubus cæsius (Linn.)—District 4.
Rubia peregrina (Linn.)—District 4.
Inula crithmoides (Linn.)—District 4.
Carduus nutans (Linn.)—District 4.
Helminthia echiioides (Gœrt.) District 4.
Orobanche minor (Linn.)—District 4.
Chenopodium rubrum (Linn.)—District 4.
Obione portulacoides (Moq.)—District 4.
Rumex maritimus (Linn.)—District 4.
Carex acuta (Linn.)—District 2 and District 4.

In this list one species, *Blysmus rufus*, is omitted, which I formerly recorded from Raven Point. I have some slight doubts about its occurrence, since I could not find a specimen amongst my collections, and I think it better to leave it uncertain till an opportunity for further search occurs.

The following flora contains a large proportion of the plants classed as Atlantic by Watson. More than half the total number found in Ireland occur on the coasts of Waterford and Wexford. Watson's Atlantic group may be divided into two sets of plants: (1) littoral or maritime, which are confined to the coast; and (2) inland species, which, though chiefly affecting maritime counties, are, in many cases, found far from the vicinity of the sea. These two sub-groups viewed separately help us to appreciate the distribution of a considerable number of species in Ireland. The first is best represented on the east and south-east of Ireland; that is to say, in the district under consideration, where, with one or two exceptions, all of them occur; the second predominates in the west and south-west of Ireland, and in this group of western species may be included several so-called "Hibernian" plants found in Kerry and Connemara, which do not occur in Britain, and are therefore not dealt with in Watson's "Cybele Britannica."

The maritime Atlantic species on the Waterford and Wexford coasts are :—

Matthiola sinuata.	Inula crithmoides.
Raphanus maritimus.	Statice occidentalis.
Viola curtisii.	Euphorbia peplis.
Lavatera arborea.	E. paralias.
Erodium maritimum.	E. portlandica.
(Daucus maritimus).	Asparagus officinalis.

Several of these do not reach the west. *Scilla verna* is the only strictly seacoast species of the group which I did not meet with, and my time of search was not sufficiently early for its discovery. It may occur, since it reaches the Wicklow coast, and is confined to the eastern and north-eastern coasts of Ireland.

The other species of Watson's Atlantic group on these coasts are :—

Coronopus didyma.	Sedum anglicum.
Linum angustifolium.	Cotyledon umbilicus.
Hypericum androsæmum.	Rubia peregrina.
H. elodes.	Orobanche hederæ.
Erodium moschatum.	Scirpus savii.

Some of these are universally distributed in Ireland ; and most of them are, like the rest of this sub-group, commoner in or confined to the west of Ireland. The few Spanish and other south European species which reach the west of Ireland, and are not dealt with in Watson's classification, will be readily included in this sub-group of his Atlantic type. I refer to such species as *Erica mediterranea*, *Dabeocia polifolia*, *Pinguicula grandiflora*, *Saxifraga umbrosa*, etc., which form the extreme type of the British development of the groups. A division including the species *Sibthorpia europea* and *Erica vagans* will naturally embrace these also. The term *Hibernian* type is, I think, objectionable and unnecessary.

[FLORA

FLORA OF THE COASTS OF WEXFORD AND WATERFORD.

[* Certainly introduced, but looking wild; ‡ probably introduced; † perhaps introduced; [] doubtfully established, and not native.]

Thalictrum minus (Linn.), var. *maritimum*.—From a little north of Courtown to about three miles south of Cahore Point, amongst sand-hills.

Ranunculus lingua (Linn.)—Swamp by the coast at Clonea, near Dungarvan in Waterford.

R. sceleratus (Linn.)—With the last, and at Lady's Island Lough, near Carnsore, Wexford. Not unfrequent, but chiefly in the estuaries.

R. baudotii (Godron)—Lady's Island Lake, at the south-eastern corner.

Glaucium luteum (Scop.)—At Greenore, Tacumshin, Ballyteigue, and Bannow in Wexford; Gararis Bay, Ardmore, and near Youghal in Waterford.

Mathiola sinuata (R. Br.)—Blackwater Head or Ballyconigar; Tinnyberna, and about five miles north of Tinnyberna below Kilmuckridge. A very rare species.

Sinapis nigra (Linn.)—Steep banks above the sea between Rosslare and Greenore, Co. Wexford. I believe it to be native here.

Cochlearia officinalis (Linn.)—Common. The sub-species *C. danica* (Linn.) occurs at the western side of Hook Head, Wexford, near the point, and near Churchtown.

**Armoracia rusticana* (Rupp.)—Established in many places, especially on the Waterford coast.

Lepidium smithii (Hook.)—Lady's Island, Co. Wexford, and a little east of Ballyvoyle Head, Co. Waterford.

‡*Senebiera coronopus* (Poiret.)—Greenore Point, and from thence increasing in Wexford. Very abundant at Hook Head. Decreasing in Waterford, and occurring only as a waste-ground plant.

†*S. didyma* (Pers.)—At Baginbun, near Fethard; about Churchtown and Duncannon in Wexford. Dunabrattin Bay, and about Annesstown; at Ballyvoyle Head, and elsewhere. More frequent in Waterford, and occurring in wilder stations than the last species.

Cakile maritima (Scop.)—Frequent.

- Raphanus maritimus* (Sm.)—Coast below Lady's Island, and between that and Tacumshin in Wexford; frequent on the steep limestone cliffs between Kilfarassy Island and Annestown, and again between Stradbally and Ballyvoyle Head in Waterford.
- Reseda lutea* (Linn.)—On a headland at Tinnyberna, Co. Wexford.
- Viola canina* (Linn.)—Sandy ground west of Crossfarnoge Point, Wexford, plentiful.
- V. curtisii* (Forst.)—Frequent where sand-hills occur.
- Saponaria officinalis* (Linn.)—Established at Lady's Island, Wexford.
- Silene anglica* (Linn.)—Tinnyberna in Wexford.
- S. maritima* (L.)—Common.
- Lychnis githago* (Lam.)—Sandy soil about the coast near Fethard in Wexford, and about Ardmore in Waterford.
- L. vespertina* (Sibth.)—About Rosslare, Wexford.
- L. diurna* (Sibth.)—Very abundant at Courtown.
- Sagina maritima* (Don.)—Frequent.
- S. nodosa* (E. Meyer.)—Frequent.
- Honkeneya peploides* (Ehrh.)—Sandy coasts. Frequent.
- Arenaria serpyllifolia* (Linn.)—Not unfrequent.
- Cerastium tetrandrum* (Curt.)—Frequent.
- C. semidecandrum* (Linn.)—Between Greenore and Carnsore Point, and sandy shores at Courtown Harbour, and north of that to Arklow. No doubt frequent. See under *Valerianella olitoria*.
- Malva moschata* (Linn.)—Cahore Point, and Lady's Island in Wexford; Tramore and Ardmore in Waterford.
- †*Lavatera arborea* (Linn.)—Kilmichael Point, Raven Point, and Rosslare Point in Wexford; always in suspicious localities; west of Newtown Head in Waterford, looking wild along the cliffs.
- Hypericum elodes* (Linn.)—Greater Saltee Island.
- H. androsæmum* (Linn.)—Occasionally, especially on thickets on the Waterford coast.
- Erodium cicutarium* (Sm.)—Frequent.
- E. moschatum* (Sm.)—Greenore Point and Churchtown in Wexford; near Tramore in Waterford.
- E. maritimum* (Sm.)—Frequent all round the coast of Wexford from Rosslare to Hook Head, and especially abundant about Crossfarnoge. This species reaches a maximum on the Wexford coast; in Waterford it has been found at Tramore ("Cyb. Hib.") I did not meet with it west of that village.
- Geranium dissectum* (Linn.)—Quite a characteristic coast species in Waterford, and looking native, which it generally does not in Ireland.

Linum angustifolium (Linn.)—Between Curracloa and Blackwater, and between Rosslare and Greenore in Wexford; Ballyernan and Ardmore Head in Waterford.

Radiola millegrana (Sm.)—Greater Saltee Island, Wexford. Very rare in the south-east of Ireland.

Ulex gallii (Planch.)—A very characteristic species along the higher headlands and rocky coasts of Waterford. *U. europæus* is remarkably showy and common in most parts of Wexford, more especially inland.

Sarothamnus scoparius (Koch.)—Baginbun, near Fethard in Wexford, and west of Tramore and Stradbally in Waterford. Not frequent along the coast, and occurring in the prostrate form at Baginbun.

Ononis arvensis (Linn.)—Locally plentiful, as on the sand-hills west of Crossfarnoge in Wexford, and about Bummahon and Knockmahon in Waterford, where a remarkably spinous form was gathered.

Trifolium pratense (Linn.)—The red clover is very abundant along the marl banks on the Wexford coast, where it is probably indigenous.

Trifolium medium (Linn.)—Near Courtown in Wexford.

T. arvense (Linn.)—Rosslare in Wexford; Kilfarassy Island, Ballydowane Bay, Helvick Head, Mime Head, and Ardmore Head in Waterford.

T. scabrum (Linn.)—A little south of Carnivan Head, near Fethard in Wexford.

T. fragiferum (Linn.)—Below Loftus Hall, on the west side of Hook Head in Wexford. See earlier part in this Report.

Lotus major (Scop.)—Saltee Island, Co. Wexford.

Anthyllis vulneraria (Linn.)—Common.

Vicia sylvatica (Linn.)—Duffcarrig rocks, north of Courtown, Wexford; at Ballyvoyle Head and Mime Head, Waterford.

V. angustifolia (Roth.)—Courtown and Rosslare in Wexford; Ardmore in Waterford.

Ornithopus perpusillus (Linn.)—Has been gathered at Ballyconigar Wexford. See "Cybele Hibernica."

Agrimonia eupatoria (Linn.)—Below Kilmuckridge, and about Rosslare in Wexford; about Ballyvoyle Head in Waterford.

Alchemilla vulgaris (Linn.)—Sandy fields by the sea north of Rosslare in Wexford; rather an unexpected habitat.

Rubus cæsius (Linn.)—South of Cahore Point, and near Morris Castle on the east coast of Wexford; and on the sand-hills west of Crossfarnoge Point on the south.

Rosa spinosissima (Linn.)—Frequent; usually abundant where it occurs.

Lythrum hyssopifolia (Linn.)—See preceding part of this report.

Epilobium hirsutum (Linn.)—Between Fethard and Baginbun in Wexford, and elsewhere.

Myriophyllum verticillatum (Linn.)—Marshy pools at Clonea, near Dungarvan, Waterford.

M. spicatum (Linn.)—In a brackish dyke inside of the sand-hills west of Crossfarnoge Point in Waterford.

<i>Lepigonum rupicola</i> (Kindb.)—	}	Frequent.
<i>L. salinum</i> (Presl.)—		
<i>L. marinum</i> (Wahlb.)—		
<i>Sedum anglicum</i> (Huds.)—	}	Common.
<i>S. acre.</i> (Linn.)—		

Cotyledon umbilicus (Linn.)—Not unfrequent where the coast is steep and rocky.

Eryngium maritimum (Linn.)—Frequent.

Apium graveolens (Linn.)—Not unfrequent, and occurring oftener on the south coast.

Oenanthe fistulosa (Linn.)—Near Bunmahon, Waterford. Rather a scarce species in Ireland.

O. lachenalii (Gomel.)—Morris Castle, Slaney Estuary, Rosslare, and Lady's Island Lake in Wexford. Clonea, near Dungarvan in Waterford. Chiefly an estuary species.

O. crocata (Linn.)—Frequent, and partial to damp places along the coast, whether brackish or otherwise.

Linum angustifolium (Linn.)—Curracloa in Wexford, and Clonea in Waterford

**Fœniculum officinale* (Ald.)—Kilmichael Point, and Curracloa in Wexford. Coast opposite Youghal in Waterford.

Crithmum maritimum (Linn.)—Common in many places, and occurring on low stony ground about three miles north of Courtown.

†*Pastinaca sativa* (Linn.)—Curracloa, Rosslare, Fethard and Duncannon in Wexford. At Rosslare this species has the appearance of a native on the sand-hills. Ardmore, &c., Waterford.

Daucus carota (Linn.)—Common. The variety *maritimus* occurs on the Waterford coast.

Torilis nodosa (Gœrt.)—Tinnyberna, and Bannow Island in Wexford; Mime Head in Waterford.

Anthriscus vulgaris (Pers.)—By the river at Lady's Island, Wexford.

Galium verum (Linn.)—Common.

Rubia peregrina (Linn.)—Sandeel Bay, south of Fethard, on the promontory of Hook, Wexford; on all the prominent bluffs and headlands on the Waterford coast.

Valerianella olitoria (Möench.)—A dwarf form flowering in early spring; grows abundantly on the sand-hills of Wexford, at Courtown, and elsewhere. It occurs similarly in Donegal, usually in company with *Cerastium tetrandum*, *C. semidecandrum*, *Draba verna*, and *Saxifraga tridactylites*. The latter two, though occurring inland, do not appear to prevail on the south-eastern coast. In the north-west their ranges are reversed, and apparently confined to the coast, or nearly so.

Dipsacus sylvestris (Linn.)—Duncannon in Wexford; at the town of Waterford.

Eupatorium cannabinum (Linn.)—Baginbun, near Fethard in Wexford, and along the steep Waterford coast near Ballyvoyle Head and Stradbally, and elsewhere.

Aster trifolium (Linn.)—Frequent.

Solidago virgaurea (Linn.)—Helvick Head, Ardmore Head, &c., along the Waterford coast.

Inula crithmoides (Linn.)—Greater Saltee Island, and Hook Head at the extreme point, plentifully, in Wexford; frequent along the Waterford coast.

Pulicaria dysenterica (Gært.)—A very plentiful and characteristic species on damp, sandy pasture in many places.

Matricaria inodora (Linn.), var. *maritima*.—Common.

Diotis maritima (Cars.)—Sandy coast below Lady's Island Lake, and Tacumshin Lake, Co. Wexford, extending for about an English mile. Also found at Tramore, Waterford.

† *Artemisia absinthium* (Linn.)—Nethertown and Lady's Island, Wexford; more frequent on the Waterford coast. Never in unquestionable localities.

Filago germanica (Linn.)—A frequent sand-hill species, especially common about Rosslare in Wexford.

F. minima (Fr.)—Very plentiful, with the last at Rosslare.

Senecio jacobæa (Linn.), var. *flosculosus*.—Cahore Point, Rosslare, and "Bar of the Lough," on the Wexford coast.

S. sylvaticus (Linn.)—Frequent on the moors along the Waterford coast.

Carlina vulgaris (Linn.)—Cahore, Rosslare, and Crossfarnogue in Wexford; Stradbally in Waterford.

Centaurea scabiosa (Linn.)—Bannow Island, and near Fethard in Wexford; Ardmore Head in Waterford.

Carduus nutans (Linn.)—On a headland by the sea near Tinnyberna, Wexford.

C. pycnocephalus (Curt.)—Frequent.

Cichorium intybus (Linn.)—Along the embankment on the north side of Wexford Harbour, and sand-hills adjoining, Ardmore Head, Waterford.

Thrincia hirta (D. C.)—Frequent, especially on the dry marl banks of the Wexford coast.

Apargia hispida (Willd.)—Rosslare, and Bannow in Wexford.

Helminthia echiioides (Gœrt.)—Between Rosslare and Greenore, and near Duncannon in Wexford; between the lighthouse and the Coastguard Station, on the north side of Dungarvan Harbour, Waterford.

Ligustrum vulgare (Linn.)—Stradbally, to Ballyvoyle Head, and elsewhere on the Waterford coast.

Chlora perfoliata (Linn.)—Cahore to Ballyconigar, in several places on the sandy pastures, and at Carnsore and Baginbun in Wexford.

Erythræa pulchella (Fries.)—Sand-hills between Rosslare Point and Rosslare, and on the Great Saltee Island, in Wexford.

E. centaurium (Pers.)—Common.

Gentiana campestris (Linn.)—Abundant in some places, as at Raven Point in Wexford, and along the cliffs west of Bunmahon in Waterford.

Convolvulus arvensis (Linn.)—Between Curracloa and Blackwater, and between Rosslare and Greenore, at Ballymadder and Bannow in Wexford; Clonea, near Dungarvan, in Waterford.

C. sepium (Linn.)—The narrow-leaved, pink-flowered variety occurs at Courtown.

C. soldanella (Linn.)—Abundant at Courtown, Rosslare, Carnsore, and all along the south coast of Wexford.

Cynoglossum officinale (Linn.)—Ballymoney, Cahore, Rosslare, Carnsore, and Churchtown, on the Wexford coast.

[*Anchusa officinalis* (Linn.)—Naturalized in sandy wastes, Rosslare Point, Co. Wexford.]

Lycopsis arvensis (Linn.)—Scarce along the coast: Raven Point, Rosslare, and “Bar of the Lough” in Wexford.

Echium vulgare (Linn.)—Killurin and Rosslare in Wexford; near Youghal, on the Waterford coast.

Lithospermum officinale (Linn.)—Shore, north of Courtown, where it was previously noticed by A. G. More.

Myosotis collina (Hoffm.)—Sand-hills north of Courtown, and in several places between that and Arklow Head.

Solanum nigrum (Linn.)—Rosslare, and “Bar of the Lough,” near Bannow, in Wexford.

Hyoscyamus niger (Linn.)—Rosslare; “Bar of the Lough,” Bannow, and Sandeel Bay, near Hook Head in Wexford.

[*Lycium barbarum* (Linn.)—Established at Rosslare Point, Co. Wexford.]

† *Orobanche minor* (Linn.)—On *Trifolium pratense*, on the marl banks by the sea below Kilmuckridge in Wexford, and elsewhere in Wexford. (See “Journal of Botany,” November, 1881).

O. hederæ (Duby.)—Strabally Cove, Waterford, plentiful. It has been previously recorded from here by Mr. T. Chandler.

Linaria elatine (Mill.)—On the shore at the Greater Saltee Island.

Lycopus europæus (Linn.)—Plentiful at Lady’s Island Lake in Wexford; near Ballyvoyle Head; and at Clonea in Waterford.

Salvia verbenaca (Linn.)—A little north of Greenore, and at Carnsore and Duncannon in Wexford; Ardmore, in Waterford.

Origanum vulgare (Linn.)—About Fethard, Co. Wexford.

Calamintha officinalis (Moench.)—Shore of Youghal Harbour, opposite Youghal, in Waterford.

Lamium incisum (Willd.)—Near Churchtown, at Carnsore Point in Wexford.

L. amplexicaule (Linn.)—Saltee Island in Wexford.

Stachys arvensis (Linn.)—Tinnyberna, Raven Point, Greenore, Saltee Island, and near Fethard in Wexford.

Ballota nigra (Linn.)—Rosslare Point, and Rosslare, Co. Wexford.

Utricularia vulgaris (Linn.)—Marsh at Clonea, near Dungarvan, Co. Waterford.

Glaux maritima (Linn.)—Frequent. A curious growth, which seems to bear no flowers, and few leaves, occurs in the brackish lake at Lady’s Island. The branches are stout and numerous.

Samolus valerandi (Linn.)—Frequent.

Statice occidentalis (Lloyd).—Baginbun Head and Hook Head, in Wexford; cliffs west of Tramore, in Waterford.

Armeria maritima (Willd.)—

Plantago coronopus (Linn.)—

P. maritima (Linn.)—

Suaeda maritima (Dum.)—

Salsola kali (Linn.)—

} Common.

} Frequent.

- Chenopodium rubrum* (Linn.)—Raven Point, Rosslare, Saltee Island, and “Bar of the Lough,” in Wexford.
- C. bonus-henricus* (Linn.)—Fethard, Co. Wexford.
- Beta maritima* (Linn.)—St. Margaret’s and Saltee Island, Wexford; frequent on the steep Waterford coast.
- Salicornia herbacea* Linn.)—Common.
- Atriplex littoralis* (Linn.)—Raven Point, Tacumshin, Kilmore, and Hook Head, in Wexford.
- A. angustifolia* (Sm.)—Frequent.
- A. hastata* (Linn.), var. *deltoidea*— } Common.
A. babingtonii (Woods).— }
- Obione portulacoides* (Moq.)—Sparingly on an insulated rock, a little north of Cahore Point, Co. Wexford.
- Rumex maritimus* (Linn.)—Plentiful at Lady’s Island Lake, Wexford.
- R. hydrolapathum* (Huds.)—Curracloa, Lady’s Island Lake, and Ballymadder, on the Wexford coast; Clonea, near Dungarvan, Waterford.
- Polygonum raii* (Bab.)—Greenore and Sandeel Bay to St. Patrick’s Bay on the west side of Hook Head, in Wexford; Clonea, and at the Kinnegar, Dungarvan and Bunmahon, Waterford.
- P. aviculare* (Linn.), var. *littoralis*—In several places on the southern Wexford coast.
- Euphorbia paralias* (Linn.)—Frequent all round the sandy coast of Wexford; between Ardmore and Youghal, in Waterford.
- [*E. peplis* (Linn.)—See previous part of this Report.]
- E. portlandica* (Linn.)—Cahore Point, Raven Point, and Crossfarnoge, in Wexford. Much scarcer than the last.
- E. exigua* (Linn.)—Sandeel Bay, on the west side of Hook Head, Wexford.
- Salix repens* (Linn.)—A very prominent sand-hill species in many places.
- Quercus robur* (Linn.)—Common along the steep Waterford coast.
- Orchis pyramidalis* (Linn.)—Sand-hills at Courtown and Curracloa, in Wexford.
- Habenaria viridis* (R. Br.)—Raven Point, in Wexford; and Ballydowane Bay, in Waterford.
- Epipactis palustris* (Linn.)—Cahore Point to Raven Point, amongst the sand-hills in many places, Co. Wexford.
- Asparagus officinalis* (Linn.)—“Bar of the Lough,” about half way between Crossfarnoge and Bannow, and at Bannow Island, Wexford.

Juncus maritimus (Sm.)—Frequent.

J. compressus (Jacq.)—Common.

J. acutus (Linn.)—Along the whole east coast of Wexford where suitable extent of sand-hills occur, and occurring also on the Waterford coast at Tramore and Dungarvan, but not on the south coast of Wexford. This handsome rush extends north nearly as far as Wicklow Head. It is more abundant south of Cahore Point, in Wexford, than in its other localities. It also occurs, sparingly, in Cork.

J. glaucus (Ehrh.)—Frequent.

Alisma ranunculoides (Linn.)—

Triglochin maritimum (Linn.)—

Typha latifolia (Linn.)—

} Clonea, Waterford. Common.

Arum maculatum (Linn.)—Abundant in thickets on sand-hills, as at Courtown.

Potamogeton pectinatus (Linn.)—Lady's Island Lake and Crossfarnoge, Wexford; Clonea, in Waterford. Local.

P. pusillus (Linn.)—Thriving in brackish water with the last species. Frequent.

Ruppia maritima (Linn.), var. *rostellata*.—Raven Point, Wexford; Clonea, Waterford.

Zannichellia palustris (Linn.)—Lady's Island Lake, Wexford; Clonea, Waterford.

Zostera marina (Linn.)—In the estuaries, abundant.

Scirpus maritimus (Linn.)—Frequent in brackish places; usually the first symptom of a river's having been influenced by the tide.

S. tabernæmontani (Gm.)—Morris Castle, Lady's Island Lake, in Wexford; Clonea, in Waterford.

S. savii (S. et M.)—Raven Point, Lady's Island Lake; and Saltee Island, in Wexford.

Carex arenaria (Linn.)—Abundant.

C. vulpina (Linn.)—Frequent.

C. paniculata (Linn.)—Clonea, Waterford.

C. acuta (Linn.)—Ballymadder, in Wexford; Clonea, Waterford.

C. pendula (Huds.)—Duffcarrig and Courtown, Wexford.

C. extensa (Good)—Raven Point, Rosslare and Saltee Island, in Wexford; Waterford, in several places in the estuaries.

C. distans (Linn.)—Frequent.

C. riparia (Curt.)—Near Kilmichael Point; and near Morris Castle, on Wexford coast.

[*Carex remota* (Linn.); *C. ovalis* (Good); *C. stricta* (Good); *C. hirta* (Linn.), and other commoner inland sedges were also observed.]

Phleum arenarium (Linn.)—Cahore Point, Raven Point, and Rosslare, in Wexford.

Psamma arenaria (R. et S.)—Common.

Glyceria aquatica (Sm.)—Tinnyberna, and abundant near Morris Castle, in Wexford; at Clonea marsh, in Waterford.

Sclerochloa maritima (Lindl.)—Common.

S. rigida (Link.)—Not unfrequent.

S. loliacea (Woods)—Wexford coast, in several places.

Festuca uniglumis (Sol.)—Courtown, Cahore, Curracloa and Raven Point, in Wexford.

F. arundinacea (Schreb.)—Frequent.

Triticum junceum (Linn.)—Frequent.

†*Elymus arenarius* (Linn.)—Raven Point, Rosslare Point, Rosslare; and at Greenore Point, on the east coast of Wexford. Probably not native.

Equisetum maximum (Lam.)—Frequent.

E. hyemale (var. *moorei*).—Along the coast of Wexford to Raven Point, frequent; not met with south of Wexford Harbour,

Asplenium marinum (Linn.)—Saltee Islands and Hook Head, Wexford; frequent on the more suitable Waterford coast.

Osmunda regalis (Linn.)—Ballydowane Bay and Helvick Head, in Waterford.

LIST OF PLANTS OBSERVED ON THE SALTEE ISLANDS.

[The letter (B) after the name of a plant implies that it was only observed on the smaller island; and when a species of interest occurred on both islands, this is denoted by the letters (A) and (B) similarly placed.]

Ranunculus hederaceus.	Lathyrus pratensis.
R. flammula.	Potentilla tormentilla.
R. repens.	P. anserina.
R. acris.	Rubus fruticosus (villicaulis?).
†Fumaria officinalis.	Lythrum salicaria.
Cardamine hirsuta.	Peplis portula.
Cochlearia officinalis.	Lepigonum marinum (B).
†Raphanus raphanistrum.	L. rupicola.
Viola sylvatica.	†Spergula arvensis.
†V. tricolor.	Sedum anglicum.
Polygala vulgaris.	Cotyledon umbilicus.
Silene maritima.	Hydrocotyle vulgaris.
Sagina procumbens.	Ænanthe crocata (B).
S. maritima.	Crithmum maritimum (A), (B).
Cerastium glomeratum.	Heracleum sphondylium.
C. triviale.	Conium maculatum.
Stellaria media.	Hedera helix (?).
Hypericum elodes.	Lonicera periclymenum.
†Geranium dissectum.	*Sherardia arvensis.
G. molle.	†Galium aparine.
Erodium maritimum (A), (B).	G. palustre.
Radiola millegrana.	†Petasites vulgaris (B).
*Ulex europæus.	Tussilago farfara.
Medicago lupulina (B).	Aster tripolium.
Trifolium pratense.	Bellis perennis.
T. repens.	Inula crithmoides.
T. minus.	Pulicaria dysenterica.
Lotus corniculatus.	†Anthemis cotula.
L. major.	Matricaria inodora.
Vicia cracca.	
V. sepium.	

† *Chrysanthemum segetum.*

Gnaphalium uliginosum.

Senecio jacobæa.

S. vulgaris.

Centaurea nigra.

Arctium minus.

Carduus palustris.

C. arvensis.

C. pycnocephalus.

Thrincia hirta (B).

Hypochæris radicata.

Apargia autumnalis.

Leontodon taraxacum.

Sonchus oleraceus.

† *S. arvensis.*

Hieracium pilosella.

Jasione montana.

Calluna vulgaris.

Erica cinerea.

Erythræa pulchella.

E. centaurium.

† *Symphytum officinale.*

Myosotis arvensis.

Linaria elatine.

Euphrasia odontites.

E. officinalis.

Pedicularis sylvatica.

Veronica chamædrys.

† *V. agrestis.*

V. serpyllifolia.

Nepeta glechoma.

Prunella vulgaris.

† *Lamium amplexicaule.*

L. purpureum.

† *Stachys arvensis.*

S. palustris.

Teucrium scorodonia.

Anagallis arvensis.

A. tenella.

Samolus valerandi (B).

Armeria maritima.

Plantago coronopus.

P. maritima.

P. lanceolata.

† *P. major.*

† *Chenopodium album.*

C. rubrum.

Beta maritima.

Atriplex babingtonii.

A. hastata.

Rumex obtusifolius.

R. crispus.

R. acetosa.

R. acetosella.

† *Polygonum aviculare* (B).

P. hydropiper.

Euphorbia helioscopia.

E. paralias.

Callitriche platycarpa.

Urtica dioica.

U. urens.

Scilla nutans.

Juncus conglomeratus.

J. supinus.

J. bufonius.

J. compressus (B).

Luzula multiflora.

Lemna minor.

Scirpus savii.

Carex arenaria (B).

C. stellulata.

C. ovalis.

C. extensa (B).

C. binervis.

Anthoxanthum odoratum.

Aira caryophyllea (B).

Agrostis alba.

Alopecurus geniculatus.

Holcus lanatus.

Arrhenatherum avenaceum.

Triticum repens (B).	Lastrea filix-mas.
Poa annua.	L. filix-foemina.
Sclerochloa maritima (B).	L. dilatata.
Festuca ovina.	Blechnum boreale.
Lolium perenne.	Pteris aquilina.
Equisetum maximum (B).	Asplenium marinum.
Polypodium vulgare.	

This list contains 153 species; probably more occur on the islands, which would require another and a longer visit in spring to make an exhaustive catalogue of their plants. There are, at any rate, four or five plants whose names do not appear in my notebook that it is hard to believe are absent. The chief interest in this list, in addition to the occurrence of some rarities mentioned in the body of this report, is the presence of a good proportion of plants belonging to Watson's Atlantic type. Of these, we have *Hypericum elodes*, *Erodium maritimum*, *Sedum anglicum*, *Cotyledon umbilicus*, *Crithmum maritimum*, *Inula crithmoides*, *Euphorbia paralias*, and *Scirpus savi*. If we look to the flora of Tory Island, as reported upon in the "Journal of Botany," 1879, by my friend Mr. Barrington, we shall find but two members of this group. This island lies at the opposite corner, on the north-west of Ireland, and is more than double the area of those under consideration. Its flora is scantier by about ten species, and of much less interest; but the comparison well shows the failure of this type as we travel northwards, in spite of the more western and Atlantic situation of the larger island.

XVI.—ON THE POSSIBILITY OF PROLONGING THE TONES OF A PIANOFORTE SO AS TO PRODUCE AN INSTRUMENT WITH THE QUALITY OF TONE OF THE PIANO, AND THE CONTINUITY OF TONE OF THE ORGAN. BY G. JOHNSTONE STONEY, M. A., D. Sc., F. R. S.

[Read, June 18, 1883.]

It is a peculiarity of the piano, the harp, the guitar, and other instruments, of which the strings are either struck or plucked, that a note even when held down dwindles in intensity; so that on such instruments no musical effect can be produced which requires each tone to be maintained throughout its continuance as loud as when first struck, as upon the organ, the violin, and most wind instruments.

Composers of piano music sometimes imitate this effect in a way which is necessarily imperfect and of limited application, by occasionally introducing into their compositions repetitions of a note or chord at very short intervals. But however rapidly the performer may execute such passages, the effect is at once felt by the ear to be very different from what such a passage would produce upon an organ—the repetitions are heard as repetitions; the note or chord is not really continuous.

This is due to two causes. Between the successive impacts of the hammer upon the string the intensity of the sound decreases; and, moreover, at each impact there is a new departure, impressing the ear as a breach of continuity. In fact, the intervals between the strokes in general consist of a broken number of vibrations, that is, of an integer number of vibrations, with the addition of some irregular fractional part of a vibration, so that the vibrations of any one of the intervals do not in general form the same series as those of the intervals that precede and follow it.

This last source of discontinuity will be removed if we have any way of securing that the successive strokes of the hammer shall fall upon the string *when it is in the same phase* of its vibra-

tion; and it would only remain to ascertain by experiment how rapidly such blows would need to be delivered to maintain a sufficient uniform intensity.

I have for some years had it in contemplation to make the necessary apparatus for applying this method to the piano, but other occupations have so long prevented me from doing so, that I now mention the subject in the hope that some other person with better opportunities and more leisure will carry out the investigation.

A perfectly continuous tone would, of course, be produced if the hammer could be made to strike the string every vibration. But it does not seem at all likely that it would be necessary to strike it every vibration—probably not more than once every twenty-five or thirty vibrations, *provided that the blow, when it does come, reaches a string which is in precisely the proper phase of its motion.* Hence, the condition to be fulfilled is, that the intervals between the blows shall be capable of being tuned into accord, if I may use the phrase, with some multiple of the period of vibration of the string. A mechanism constructed so as to deliver an impact at each swing of a short pendulum, of a balance-wheel, or of a very large tuning-fork, might be adjusted to the string, or the string tuned to it, in the way required; and an apparatus regulated in this way, if applied to a piano with good repeating action, might be made to impinge directly on one of the ivory keys, which would probably be the easiest way of making a sufficient *preliminary* experiment, without a specially-constructed piano. A weight or spring acting on very simple clock-work would suffice as the motive force; or, perhaps, electricity could be conveniently employed; but I think it would be found easier to render the arrangement sufficiently noiseless with a purely mechanical apparatus, avoiding electricity. Should the ticking or other noise of the apparatus for the preliminary experiment be troublesome, the apparatus will need to be boxed in or the noisy parts placed in an adjoining room.

If the anticipated result can be attained, an entirely new range of musical effects will be at our disposal, for we shall have within our reach an instrument with the quality of tone of the piano—one of the most pleasing qualities of tone among musical instruments—and on which much of the best organ music can be executed.

XVII.—NOTE ON THE EFFECT OF FLEXURE ON THE PERFORMANCE OF TELESCOPIC OBJECTIVES. BY HOWARD GRUBB, F. R. S.

[Read, June 18, 1883.]

DURING my work on the 27-inch objective for the Vienna Refractor, I was led to study more closely than heretofore the effect of flexure on one or both lenses of a large objective, and as the results which I arrived at, both in actual practice and on consideration of the subject theoretically, were very different to what might at first sight be considered natural, I thought it might be interesting to place the matter on record.

Let me first, however, explain that this flexure is of most serious consequence in the preparation of object-glasses of large size. It may be thought by those not conversant with the subject that any flexure that could occur in a disc of glass, say of twenty-four inches diameter and from one to two inches thick, from, or due to, its own weight, must be so infinitesimal as might be fairly neglected in the general results; but this is not so. I can easily demonstrate to you that such flexure is a mechanically measurable quantity, and one-tenth of the smallest quantity thus measurable would be quite sufficient to make all the difference between a good objective and a bad one.

This last assertion I am not in a position to demonstrate, but anyone who has attempted to make an objective or a speculum for a reflecting telescope will bear me out in what I say.

The flexure that I propose to consider in this communication is that due to the weight of the disc of glass itself, which alters the figure or shape of the disc as it lies in its cell, supported round the edge only on three fixed points, or on three fixed and any number of adjustable points, but in all cases round the edge only. So long as the glass is on its polishing machine undergoing the various processes of grinding, polishing, figuring, &c., it can be supported on a perfectly equable support of some kind, such as reflectors are laid on both for manipulation and for actual working; but it is

evident that in the case of a refractor no supports are admissible once it is placed in its tube, except on a narrow band round the extreme circumference. It is therefore evident that the most perfect support we can give can only go so far as to support it equally round the whole circumference.

The whole lens, therefore, alters its shape in accordance with the altitude of the object under examination: the higher the altitude, in the case of the crown lens, the less convex the first surface becomes and the more convex the second. This, in a moderately thin lens, becomes a measurable quantity; but provided the support be perfectly equable round the whole circumference, the effect on the image is imperceptible: it is practically the same, in fact, as if the first surface were increased in radius by an almost infinitesimal amount, and the second diminished by the same, the gross result being almost exactly the same. In general, too, it may be assumed that any flexure which does not cause one or other of the surfaces to cease to be a surface of revolution is of no consequence, unless, indeed, it amounts to such a quantity as to cause polarization.

When, however, a large thin lens is supported on three fixed points only round its circumference, or that, from any cause, the support is not equable round the edges, there must be, and is, a considerable variation from a surface of revolution, and as this flexure will naturally increase largely as the thickness of the lens diminishes, I have been much surprised to find the effect on the image due to this flexure no more troublesome in thin lenses than in thick, and this it is that has led me to investigate the matter.

The general result of my investigations is rather remarkable, and goes to show that in the more usual construction of telescopic objectives, and supposing all the surfaces to be truly surfaces of revolution as they came from the polishing machine, the thickness of the lenses (within moderate limits) is of very little consequence, and for the following reasons:—

The flexure of the glass we may probably assume to follow the ordinary law, as being inversely proportional to the square of the thickness for any given weight or load; but as the weight of the glass itself diminishes directly as the thickness, the flexure due to its own weight will be just inversely as the thickness (not as square of the thickness). But now as to the effect on the image. If the lens were infinitely thin, the effect would be *nil*, for wherever

one surface got convex the other would get concave by an equal amount; and the only reason why flexure in a lens does distort the image is, that after the rays are disturbed from their true path, by the alteration of curvature of first surface, they have to travel some distance (*i. e.* the thickness of the lens) before they are corrected by the other; and the effect, therefore, of any given flexure on the image varies directly as the thickness (almost exactly for moderate thickness).

As, therefore, the flexure varies *inversely* as the thickness, and the effect of that flexure varies *directly* as the thickness, it follows that the effect on the image, from flexure of the discs due to their own weight, is about equal, no matter what the thickness is.

This curious result explains to me how it is that we just as often find evidence of flexure in thick as in thin lenses, and other formerly puzzling matters.

The above result is only strictly true when the bending or refraction is equal on both surfaces, which is approximately the case with the crown lens of the ordinary form of telescopic objectives, but not with the flint; from which it follows that it is more necessary to have thickness in the flint than in the crown.

It is well known among opticians that this is practically the case, but the reason generally assigned is, either that the form of the flint is not so well calculated to resist flexure, or that the specific gravity being higher, the load is really greater.

It would, however, appear now that there are other reasons.

It also follows from the above that objectives constructed on the "Gauss" system, in which the refraction is very different on the different surfaces, will suffer more from any flexure due to their own weight than those constructed on the more ordinary system.

XVIII. — ON SOME CURIOUS NUMERICAL RELATIONS OF
THE MUSICAL SCALE. BY JOCELYN H. THOMSON,
LIEUTENANT, ROYAL ARTILLERY.

[Read, June 18, 1883.]

THE accompanying Table represents an octave divided into forty-seven parts, in such a manner as to give twenty-four complete major keys with perfect intervals, namely, those whose tonics are marked with an asterisk. All these keys, except those of $A\flat\flat_2$, $C\flat_1$, and $E\flat\flat_1$, have their minor scales also complete.

Column I. of the Table gives the names of the notes, the figure below each serving to distinguish it when there is more than one of the same name. Column II. gives the different keys to which each note belongs. Column III. gives the fractions representing the ratio of the number of vibrations of the note to that of C_1 . Column IV. gives the same ratio expressed as a logarithm. From the principle of logarithms it is evident that this column gives the numerical value of the interval from C_1 . Column VI. gives the logarithms, and, consequently, the numerical values of the intervals in a scale of equal temperament; *i. e.* a scale in which the octave is divided into twelve equal parts, or semitones. Most modern keyed instruments are tuned to equal temperament, which system offers so many advantages, as to counterbalance the disadvantage that no interval is absolutely perfect.

Since Column VI. gives the numerical value of the interval in a scale of equal temperament, and Column IV. that of the true interval, the difference between these two will give a measure of the discord between the notes on the two scales. This difference is given in Column VII. Now, on an inspection of this column, the following points will be noticed:—First, that the numbers on either side of the centre of the scale are equal, but of opposite sign. This is merely due to the fact that in both scales each interval from the lower C has a corresponding interval from the upper; or, in other words, both scales are symmetrical. Next, it will be noticed

that the discord is least in the case of the sub-dominant and dominant, which are the principal notes after the tonic in any scale. The third point to be noticed is, that all the numbers in this column are approximate multiples of one constant: $(a) = .0004904$ or $.009587$ of a tone $(\frac{9}{8})$.¹ This is shown in column VIII. Returning to Column IV., it will be noticed that the last three figures of the logarithms follow a system. This points to the fact that there is a relation between the distances apart of successive notes. In every group of four the two outer intervals are equal to $11a$, and the inner one to $10a$. We will call the former P , and the latter Q . The interval P is one that constantly recurs in the mathematical treatment of the musical scale. It is, in fact, the major Comma $(\frac{81}{80})$, and is the difference between the Major Tone $(\frac{9}{8})$ and the Minor $(\frac{10}{9})$. The interval Q is called the Minor Comma $(\frac{2048}{2025})$. It is the difference between the Enharmonic Diesis $(\frac{128}{125})$ and the Major Comma, the Enharmonic Diesis, being the difference between the Major Semitone $(\frac{16}{15})$ and the Minor $(\frac{5}{4})$. The intervals between successive groups of four involve a third quantity $R(\frac{15625}{15552})$, which may be called the Diminished Comma. This interval is the difference between three minor semitones and a major tone. The three constants P, Q, R give a convenient measure of the intervals from C, of all the notes in the above scale; and, moreover, any musical interval which can be formed from the diatonic scale may be expressed in simple terms of P, Q, R .

NOTE ADDED IN THE PRESS.

Since the fractions representing musical intervals must be multiplied together in order to obtain the fraction representing the sum of those intervals, therefore the quantity $34P + 19Q + 12R$ (the octave) is really equivalent to $\left(\frac{81}{80}\right)^{34} \times \left(\frac{2048}{2025}\right)^{19} \times \left(\frac{15625}{15552}\right)^{12}$. This fraction when mul-

¹ This relation depends on the coincidence that 2^{173} is nearly equal to $10^{12} \times 3^{84}$; for if

$$2^{173} = 10^{12} \times 3^{84},$$

then

$$173 \log 2 = 12 + 84 \log 3$$

$$4 \log 2 + 49 \log 2 + 84 \log 2 + 24 \log 2 + 12 \log 2 = 84 \log 3 + 12,$$

$$\frac{4}{12} \log 2 + \frac{49}{12} \log 2 + 7 \log 2 + \log 4 + \log 2 = 7 \log 3 + 1,$$

$$\frac{4}{12} \log 2 - 1 + \log 2 + \log 4 = 7 (\log 3 - \log 2 - \frac{7}{12} \log 2),$$

$$\frac{4}{12} \log 2 - \log \frac{5}{4} = -7 (\frac{7}{12} \log 2 - \log \frac{3}{2}),$$

tiplied out has 179 digits in the numerator; and yet, when reduced to its lowest terms, it is exactly equal to 2. Consequently, it accurately represents the interval of the octave.

which proves that the differences for the dominant and the mediant are commensurable. But the diatonic scale is made up of combinations of the major fifth and major third; consequently, if the dominant and mediant have differences which are multiples of a constant, then the other degrees of the scale will have the same property.

Again, if the relation holds good for one diatonic scale, it will also hold good for any others that are built up on it; for the difference of any degree in a scale built on to the primary scale must be equal to the difference due to that degree plus the difference belonging to the tonic on which the scale is formed. For example:— $F_2^{\sharp}$ is the supertonic of E_2 . Now the difference for the supertonic is $-2a$, and the difference for E_2 is $+7a$. Consequently the difference for $F_2^{\sharp}$ is $+5a$. N. B.—The equality of the above last equation is not exact, the left side being $7 \cdot 000490474126$, and the right $7 \cdot 000490428252$.

XIX.—NOTE ON THE AMYGDALOIDAL LIMESTONE OF
DOWNHILL, CO. DERRY. BY PROFESSOR J. P.
O'REILLY, M.R.I.A.

[Read, May 21, 1883.]

SOME months ago I received from Professor Hull a set of specimens forwarded to him by Mr. Egan, of the Geological Survey. He described them as filling cavities in sheets of basalt at Downhill, county Derry, and added, "It seems to be the curious mineral mentioned by Portlock (p. 215 of his Report) as occurring in that locality." Mr. Egan further mentions, that a similar mineral is to be found at Ballymoney, Co. Antrim, associated with calcedony, and near Limavady, Co. Derry, where, in common with a hard, flinty breccia (such as occurs between the chalk and the basalt in various places along the great basalt escarpment), it appears to have its origin in masses of chalk and flint caught up in the basalt.

Portlock thus describes the mineral:—"A curious mineral occurs in soft amygdaloid at Downhill. It is oolitic in structure, consisting of spheroids cemented together by pure white carbonate of lime or by green earth. In the latter case it has much the appearance of pudding-stone. The spheroids are yellow, whitish, or greenish, and appear to be a mixture of the hydrocarbonates of lime and magnesia. The small cavities are lined with drusy crystals of pure white carbonate of lime: where exposed, the cement, yielding first, assumes a mammillated appearance."¹

He further adds, that the greenish aragonite of Ballintoy and the brownish aragonite of Downhill both contain a sensible amount of strontian.

The samples forwarded by Mr. Egan show the more usual forms of occurrence of the mineral and the rarer forms. There is also one showing "obscurely the manner in which the mineral is often associated with aragonite."

¹ Geological Report on Londonderry, p. 215.

The greater number of the samples show an oolitic structure, such as is mentioned by Portlock, only that in none of them is the cement of green earth, some of this mineral being, however, present on one or two of the specimens.

It may be taken for granted that the samples forwarded are of the same nature as those alluded to by Portlock. The question is, Are they hydrocarbonates of lime and magnesia, as he presumes—that is to say, hydrodolomite, as suggested by Mr. Egan?

A fair sample of one of the specimens was analysed by Mr. Templeton, one of the students of the Royal College of Science, and the following are the results:—

CaO,	54.69
MgO,	0.55
Al ¹ O ³ & Fe ² O ³ ,	0.87
Insoluble matter,	0.54
CO ² ,	43.54
Moisture,	0.31
	100.50

A portion of this same sample gave a density of 2.722. Hydrodolomite, according to Dana, has a density of 2.495; therefore, neither by analysis nor by density can this mineral be described as hydro-dolomite: both would make it simply carbonate of lime relatively pure.

However, the examination of the hardness showed that the white oolites cut ordinary limespar; therefore they must have a hardness greater than 3. Aragonite crystals they do not cut, both minerals appearing to resist about equally. The hardness of the oolites may therefore be taken at 3.5. The density, being merely that of pure calcite, would seem to argue against its being aragonite; but Naumann gives for aragonite in the *aggregated form*, as lowest limit of density, 2.7. These oolites are, strictly speaking, aggregates, and the density of 2.722 is admissible for their being aragonites. On the other hand, this density excludes the assumption of their being dolomites, the limits of density for which are 2.8 to 2.95.

In order, however, to test this point, samples were submitted to the action of acetic acid, which in all cases rapidly decomposed

the oolitic parts, but only partially, and in certain parts, in no ways, attacked the matrix of the oolites.

This matrix has a distinct colour and crystalline structure, but so far I have been unable to separate it in sufficient quantity to get its density. However, it would seem from the foregoing considerations that this mineral is really constituted of oolitic aragonite in a matrix which presents to a greater or less extent the character of dolomite.

XX.—ON AN APPARATUS FOR OBTAINING TELEGRAPHICALLY THE READINGS OF METEOROLOGICAL INSTRUMENTS PLACED AT A DISTANCE FROM THE OBSERVER. (Plates III. and IV.) BY J. JOLY.

[Read, February 19, 1883.]

THE contrivance described in this Paper is one which may be attached or adapted to the various thermometers, the barometer, rain-gauge, and to some others of the instruments installed, say, in a mountain station, enabling their readings to be taken from a conveniently-placed observatory.

It is submitted that the arrangements are not of a costly nature, or more complicated mechanically than those daily in use in every telegraph office. The proposal for a distributor, as described in the latter part of the Paper, is advanced with more diffidence, as it has not yet been practically tested.

A brief generalization of the method proposed will be of assistance in subsequently considering the details of the apparatus.

To take the case of a thermometer: its stem is left open, a fine wire being arranged to move freely upwards or downwards within it. An electro-magnet forms part of the contrivance—which we will suppose is some miles distant from the observer. The electro-magnet is, however, in circuit with the home station, and matters are so arranged between it and the movable wire, that each time a current is sent from the home station to the electro-magnet the wire is advanced *downwards* by a certain amount. Say this advance is the $\frac{1}{100}$ th of an inch. If fifty makes and breaks are effected in the home station, the wire in the instrument will have moved downwards by half an inch. Suppose, now, that a return circuit connects the mercury in the thermometer with the home station, so that, as soon as the descending wire meets the mercury where it stands in the tube of the thermometer, the current supplying the electro-magnet will be returned by the circuit, causing a galvanometer in the home station to deflect. The mo-

ment of contact will, by this means, be known to the observer; and if, further, the position of the movable wire, when started on its downward course, was known to him, a record of the number of contacts will give him the reading of the thermometer or other instrument.

In Plate III. a plan and sectional elevation of the necessary mechanical arrangements are given.

The vertical shaft or spindle, *s*, shown in section in the plan, is pivoted at each extremity, so as to turn freely on its axes. It carries for a portion of its length a screw thread, which, as shown, has a pitch of $\frac{1}{10}$ th of an inch. It also carries a small wheel, notched with triangular teeth, twenty in number. A still smaller wheel, *w* (elevation), gears with the cogged wheel, *w'*, so that, as will be readily understood from the figure, the spindle *s*, in turning on its axes, either moves or is moved by the weight, *P*, contained in the hollow pillar supporting the apparatus.

A nut carrying a horizontal arm, *f*, bites on the screw. This arm is held from rotating with the screw by the vertical guides *o, o*. The rotation of the screw, therefore, imparts a vertical motion to the limb *f*. The fine platinum wire, *p* (elevation), hangs loosely from the extremity of *f*; it is, in fact, retained from falling through an aperture provided for it by a small enlargement or stop. A thermometer, *t*, is so placed, that vertical motion imparted to *f* raises or lowers this wire in its tube, which, to that end, is left open.

Two pairs of electro-magnets are shown in plan. One of these, *e, e*, serves to impart motion to the triangular-toothed wheel, and hence to the screw, which it turns in such a direction as to *lower* the platinum wire into the tube of the thermometer. The other pair, *e', e'*, serves to release the wheel from the control of the pallet, *g*, so that the descent of the weight *P* (*raised* at the same time that *f* was being urged downwards) may restore the arm *f* and wire *p* to their highest positions. The return wires from both electro-magnets are put to earth through a small resistance. An adjustable and insulated limb, for contact with the wire *p* when in its highest position, is shown at *n* (elevation). A single wire from the home station branches to this and to the mercury in the thermometer. Two more wires are needed—one to *e, e*, another to *e', e'*. A reading is effected as follows:—

A rheotome at the home station puts the wire leading to e, e for a moment into circuit with a battery.¹ If the platinum wire p is in its highest position, as it should be, and hence in contact with n , the current will, during the first instant, return by the wire common to n and to the thermometer—*i.e.* by wire No. III. This fact is known at the home station by the deflection of a galvanometer in circuit with wire No. III. The magnet e, e , however, immediately attracts up an armature attached to the arm i . This arm is hinged at one extremity; at the other it carries a smooth steel pallet, x . The pallet, on moving forward, engages with one of the triangular teeth, turning the wheel through such a distance that a second pallet, g , just gets over another of the teeth, and, on the current being turned off, and the first pallet being restored to its neutral position by the agency of the spring 2, completes the turning of the wheel through one tooth. One make and break, then, of the rheotome serves to turn the wheel and screw by $\frac{1}{20}$ th of a revolution (as there are twenty teeth provided). The screw, however, has a pitch of $\frac{1}{10}$ th of an inch; hence a motion downwards of $\frac{1}{200}$ th of an inch has been imparted to the wire p . The weight P has also been raised through a certain distance. A second make and break of the rheotome urges the wire downwards by another $\frac{1}{200}$ th of an inch; and so on. Ultimately, when the wire reaches the mercury in the thermometer, a second deflection of the galvanometer on wire No. III. in the home station takes place. The number of contacts made is read on the rheotome, and the height of the thermometer deduced.

Contact is now made for a few seconds between wire No. II. and the battery. The effect on the instrument is, that by the motion of the arm i towards the electro-magnet e', e' , the pallet x , moving backwards, lifts the second pallet, g , out of the wheel, and so liberates the wheel to the action of the weight P . The limb f and wire p are consequently run up to their highest positions, on attaining which a deflection of the galvanometer once more occurs, and the observer in the home station breaks contact.

The object of having the wire p hung loosely on the arm f , instead of having it firmly attached to it, is probably apparent.

¹ If the instrument be very far removed from the home station, a relay to supply the necessary current to the electro-magnets will be required.

In the latter case, if failure of proper contact between the wire and the mercury occurred, the observer might damage the thermometer by urging the wire below the surface of the mercury. As arranged, the wire, under such circumstances, would merely rest on the surface of the mercury, however far f was urged downwards.

The weight P might perhaps with advantage be dispensed with in favour of a spring coiled in a drum fixed on w' . With the dimensions shown, this spring would be subject to five turns during the complete descent of the wire.

This arrangement, being of a purely mechanical type, admits of many variations. One form has been made for me by Mr. Yeates, in which the elevation of the wire is effected by rotating the toothed wheel in the opposite direction by the second electromagnet. The contrivance for effecting this is due to Mr. Yeates. In this case the screw itself advances downwards or upwards, carrying the platinum wire attached to its extremity. The screw bites in a nut borne by the toothed wheel, but is held from turning with it, being slotted longitudinally, a fixed pin projecting into the slot. Such a form, although found to work very satisfactorily, has the great disadvantage of requiring as many makes and breaks of circuit to lift the wire out of the thermometer as to take the reading in the first instance. The quick return in the present arrangement does away with this objection.¹

It will be noticed that three wires are needed to work the instrument—one to each magnet—that is, one to lower the movable wire, and one to raise it, a third being necessary to notify the position of the wire, whether in contact with the starting-point contact or with the mercury contact. Now, it will be obvious that this third wire might be common to any number of instruments contained in an observatory, and the second wire might be dispensed with by the addition to each instrument of an arrangement

¹ The instrument constructed for me reads to the $\frac{1}{40}$ th of a degree Fahrenheit. This delicacy is unnecessary, and has the disadvantage of making reading a slow and tedious operation. Its certainty of action is all that could be desired. In the form proposed above a delicacy of $\frac{1}{8}$ th of a degree Centigrade is intended, each degree causing a rise of about $\frac{1}{40}$ th of an inch in the mercury.

A little glycerine is placed over the column of mercury in the thermometer, to exclude air bubbles.

for automatically shunting the current from the electro-magnets e, e to the electro-magnets e', e' on contact being made with the mercury, or on *complete* descent of the wire. In any case, as described, the number of wires making up the cable going to the observatory would not, for n instruments, exceed $2n + 1$.

Any number of instruments, however, may, I venture to think, be worked with perfect reliability and certainty by the use of three wires only. Plate IV. will show how this is accomplished, the only extra piece of apparatus needed being a disc,¹ carrying insulated contact pieces arranged round its circumference. To these the wires, &c., of the different instruments are attached. Of the three needful wires, then, i. serves to put one after the other of the contacts into circuit with the home station through wire ii. By this second wire the readings are taken and the readjustment of the instruments effected. The arrangement by which the current through i. puts the wire ii. in communication successively with the several contacts will be understood from the figure and from the foregoing description of a similar mechanical contrivance in the case of the thermometer. Wire iii. for indication of the contacts, is taken from all the instruments to the galvanometer in the home station.

One of the wires in the observatory is shown on the diagram as a "test wire." When the movable hand arrives at the contact piece attached to this wire, the current on i. returns through ii. to the home station. If, therefore, at any time a check on the position of the hand of the distributor in reference to the indications of the commutator at the home station is desired, it is only necessary to work the commutator, ii. being put in connexion with the galvanometer.

The operations involved in taking a reading are obvious. The commutator is first worked till the required instrument is in circuit—that is, the hand of the commutator is put over the *first* contact devoted to that instrument. The rheotome on wire ii. is now brought into action. In starting it, a deflection of the galvanometer on iii. shows that the contacts are being truly reckoned from the zero point of the distant instrument. The hand of the rheotome is now steadily turned till a second deflection of the

² Plate IV. is diagrammatic only.

galvanometer shows that the descending wire in the instrument has reached the mercury level. The rheotome is provided with a counter, on which the number of contacts is recorded. Reference to a Table gives at sight the reading of the instrument. This being recorded, the commutator hand is moved over the next contact, *i.e.* the *second* devoted to the instrument in question. The current through the rheotome has now been shunted at the instrument; the galvanometer for a moment returns to its zero position, but is immediately deflected again by the readjustment of the instrument into contact with wire *III.* In the interval the movable limb of the distant instrument has returned to its starting-point.

These operations being consecutive and of a purely mechanical nature, it will be evident that a clockwork arrangement, to take automatically the readings of the various instruments and record them on divided paper, need not be very complicated or expensive. It will suffice to indicate briefly the nature of such an arrangement.

A drum bearing divided paper is provided with a metallic stud at one extremity. This stud moves over the disc of the commutator, shown in Plate IV. as attached to wire *I.* Intermittent motion is imparted to the drum through a suitable cam. The intervals of rest are alternately long and short. That is, at a *reading* contact it halts, say, for two minutes, the reading being taken and recorded on the drum; it moves forward, resting for, say, thirty seconds at the succeeding contact piece, while the instrument which has just been read is being restored to its zero position. Its next halt is again for two minutes, when another instrument will be in circuit; and so on, the paper on the drum being divided into longitudinal divisions for the separate record of each succeeding instrument.

Parallel to the axis of the drum, and attached axially to the movable arm of the rheotome (on wire *II.*), a spindle carrying a screw thread revolves. The screw may be a fac-simile or an enlargement of those on the distant instruments. A carriage, with small pricker attached, moves on the screw. Separate clockwork may work the rheotome, but gearing with the commutator is provided, so that, on the drum coming to rest over a contact, the

rheotome is started, and continues making and breaking circuit on wire II., moving the carriage and pricker at the same time longitudinally in front of the drum. When, after a certain number of contacts, the current returns by wire III., a small electro-magnet comes into action, which is so arranged as to throw the rheotome out of gear, and simultaneously press the pricker forward on the paper carrying the drum. The reading is now recorded on the drum. The next movement of the drum to the succeeding contact allows of the adjustment of the distant instrument, and also of the carriage carrying the pricker.

In conclusion, the following suggestions as to the forms which might be given to some of the instruments may not be out of place.

In the case of the barometer, the siphon form of the instrument would be used, probably with wide vacuum chamber and narrow air surface. The thermometer, wet bulb thermometer, solar radiation thermometer, and terrestrial radiation thermometer, are suitable, as already described, with such modifications as the free and uninfluenced readings of the instruments in their several positions demand. For the rain-gauge I would suggest the following arrangement:—

The rain, collected in a suitable vessel, is conducted into a vertical cylinder, which forms the longer branch of a U tube. This tube contains mercury, the level of which in the shorter limb is read in ascertaining the rainfall. The height to which the mercury would be raised for a given fall of rain on a given receiving surface is a question of the relative diameters of the two branches. The receiving surface being eight inches in diameter, it is easy to adopt such a diameter for the containing vessel that the pressure due to one inch of rainfall, say, since last reading, shall be represented by some three or four inches rise of the mercury. For the purpose of emptying the water-vessel after each reading, an electro-magnet is arranged to open a valve at the base of the vessel. The current to this electro-magnet is interrupted automatically when the water has fallen to a certain zero level. This is effected by passing it through the mercury column in the short limb of the tube, the fall of the mercury breaking the circuit at the desired point.

Wind velocity, if treated by a Robinson's anemometer, might be converted into and read as a vertical movement by an arrangement like that described by Professor Perry (*Practical Mechanics*, p. 241). Wind pressure would be more easily dealt with.

An anemoscope would also be needed. This might consist of a disc, traversed by a metallic sector, attached to an exposed vane, the position of the sector, and so the direction of the wind, being ascertained by successive contacts.

XXI.—THE OSTEOLOGY AND ARTHROLOGY OF THE HAD-
DOCK (*GADUS AEGLEFINUS*). BY H. ST. JOHN
BROOKS, B. A., M. B., B. CH., SENIOR MODERATOR IN
NATURAL SCIENCE, UNIV. DUB.; DEMONSTRATOR OF ANATOMY,
CARMICHAEL COLLEGE OF MEDICINE. (Plates V.—IX.) [Com-
municated by ALEXANDER MACALISTER, M. D., F. R. S.]

[Read, November 19, 1883.]

IN this Paper is given a detailed description of the osteology and arthrology of a single type of Teleostean fish. In a work of this kind there is not likely to be found anything new, although several things in it are new to me, such as the existence of a cartilaginous rod passing from the atlas into the exoccipital bone, the peculiarity of the articulation of the first rib, the existence of a structure which is probably the homologue of the lower labial cartilage of the Elasmobranch fish, &c.

It will be convenient to adopt the usual classification of the vertebrate skeleton into *axial* and *appendicular* parts—the former comprising the skull and vertebral column; the latter, the shoulder and pelvic girdles, with the bony axes of the limbs: to these may be added, in fishes, the interspinous bones and fin-rays.

The skull may be divided into the cranium, or brain-case, and the bones of the face, the latter including the suspensorium and gill arches and the operculum, or gill cover.

The cranium is composed of the following bones: the supra-occipital, frontal, and mesethmoid form the roof from behind forwards in the middle line; more laterally, the parietal, epiotic, pterotic, and sphenotic, the two latter appearing also in the lateral walls, and the epiotic in the posterior wall; laterally the skull is bounded by the pterotic, opisthotic, sphenotic, prootic, alisphenoid, and prefrontal or ectethmoid; posteriorly by the supraoccipital, epiotic, exoccipital, and small parts of opisthotic and basioccipital (see Pl. V., figs. 1, 2, and 3). The floor is formed by the basioccipital, prootic, and prefrontal, and is closed below the middle portion by a membranous interorbital septum.

If the fresh head be boiled for a short time, all but two of the facial bones (the parasphenoid and vomer) will become detached. These two bones will remain strongly connected to the brain-case, but are not included among the bones of the cranium, as the prootic bends inwards, and articulates with its fellow of the opposite side above the parasphenoid, thus entirely excluding the latter bone. The prefrontals in the same way exclude the vomer. The mesethmoid and prefrontal do not appear at first sight to form parts of the brain-case, but it will be remembered that the olfactory nerves pass out between the frontal and prefrontal, and end in the olfactory bulbs (Pl. VII., fig. 13, 3), which are morphologically part of the brain. These bulbs lie on the prefrontal, in a hollow bounded by the mesethmoid in front, partly roofed by the same, and bounded laterally by membrane. From between the mesethmoid and prefrontal a strong rod of cartilage projects backwards above the parasphenoid and vomer; the membranous interorbital septum splits to enclose this, and is attached to the parasphenoid below.

The hyomandibular, with the symplectic and quadrate, forms the suspensorium. The quadrate, connected to the palate by the three pterygoids, forms, with these bones, the palato-quadrate arch. Thus, from the palate to the hyomandibular there is an immovably articulated chain of bones (Pl. VI., fig. 5), which is strengthened by a strong splint, the preoperculum, which is united by suture to the quadrate and hyomandibular. This arch articulates in two places with the skull; the head of the hyomandibular with a cavity formed by the pterotic, prootic, and sphenotic bones; and the angle of the palate bone with a cartilaginous eminence developed on the junction of the prefrontal and vomer. It is also suspended to the anterior end of the skull by strong ligaments. The quadrate furnishes an articular condyle to the mandible.

The orbit is bounded above by the frontal and prefrontal. To the side of the latter is articulated a rather large lachrymal, to the back of which is attached a chain of five small suborbital bones, the last of which articulates with a projecting angle of the frontal, thus surrounding the orbit with a bony ring. The lachrymal projects forwards in front of the orbit, overlapping the upper ends of the maxilla and premaxilla, and its internal edge is joined by ligamentous fibres to the nasal, the inner edge of which is connected in a similar way to the ethmoid. The posterior portion of

the nasal bone overlies the nasal sacs. Other facial bones are the maxilla and premaxilla, and, connecting the skull with the shoulder girdle, is a forked post-temporal bone, from the concavity of which three small scales of bone pass to the inner, and one to the outer, ridge of the pterotic bone. Before passing to the hyoid apparatus and gills, a more particular description may be given of the above-mentioned bones.

The frontal is the largest bone in the skull, and consists of two lateral halves fused. From the back of the upper surface projects an elevated ridge, which is continuous with the crest of the supraoccipital, the latter being wedged into a deep groove behind it. At the sides of this are a pair of ridges, continuous with the inner ridges of the pterotics. These ridges are undermined from the outer side by deep grooves, which lodge mucous glandular tissue in the recent state. They communicate with a pair of curious oval apertures, which lie in front of the central ridge. Laterally the bone projects over the orbit, forming its roof. On the under surface are seen two curved ridges, the anterior ends of which articulate with the prefrontals, and the posterior with the alisphe-noids. Just external to the articulation with the prefrontal is a groove, through which the nasal branch of the trigeminal nerve passes, and external to this the bone again articulates with the prefrontal. Stretching forwards over the latter, the frontal articulates with the ethmoid. Posteriorly it articulates with the sphenotic, parietal, and supraoccipital, and only just touches the inner ridge of the pterotic. The frontal overlaps every bone with which it articulates.

The supraoccipital consists of a large elevated crest, continuous with the median ridge of the frontal, and of two small lateral portions. These articulate with the epiotics externally, and the articulations are overlapped by the parietals, which also articulate with the supraoccipital farther in front. The under surface of the crest articulates below with the exoccipitals, and the latter, uniting together, exclude the supraoccipital from the foramen magnum; in front it articulates with the frontal. The back of the crest is closely connected by ligamentous fibres to the neural spine of the atlas.

The parietal is a curved scale of bone, presenting a well-marked ridge, which runs from before backwards, with an inclination out-

wards. Just below this ridge it is perforated for a branch of the trigeminal nerve. It overlaps all the bones of the cranium with which it articulates, except the frontal. If the skull be softened in boiling water, it can be easily raised without disturbing the other bones. It is then seen to bridge over the hiatus¹ between the supraoccipital and pterotic bones, both of which it overlaps for some distance. It articulates also with the epiotic, sphenotic, frontal, and just touches the alisphenoid. The tip of the inner limb of the post-temporal fits into a groove on the upper surface behind.

The epiotic is a very small bone, presenting a superior and an external surface, placed at right angles to each other, and a narrow posterior surface; above it articulates with the parietal, and just behind this supports the inner limb of the post-temporal; internally it joins the supraoccipital; below, the exoccipital, and externally the pterotic and opisthotic. Its cerebral surface is excavated by the posterior vertical semicircular canal.

The exoccipital (Pl. VI., fig. 6) presents on its posterior surface a convexity from side to side, and a concavity from above downwards. The convexity forms a ridge, which is bent in such a manner as to present a concavity outwards, which overhangs a large foramen in the upper end of the bone for the vagus nerve. Below, the ridge ends in a sub-cylindrical extremity, which articulates with a process of the body of the atlas. Internal to the ridge, near where it joins the atlas, is a foramen for the first spinal nerve. The two exoccipitals, with the basioccipital, bound the foramen magnum. The inner borders articulate above with the supraoccipital; below,² with each other. The sutures seen on the outside of the skull are with the supraoccipital, epiotic, opisthotic, and basioccipital. The outer portion of the bone stretches forwards on the inner surface of the opisthotic (inside the skull), and is connected to the prootic and pterotic by a strip of cartilage. The upper part of the cerebral surface of the bone is notched by the lower crus of the posterior vertical semicircular canal; and just below the internal opening of the foramen for the vagus nerve is a slender, foot-like process, which, articulating with a ridge on the upper surface of the basi-

¹ This space is also closed partially by cartilage, which underlies the parietal.

² That is, by the edges of the surface which is turned towards the commencement of the spinal cord.

occipital, forms a bony hoop, which supports the large otolith, being applied against the posterior end of its inner convex surface.¹

The opisthotic is a thin bone, which is bent in such a manner as to present a notch posteriorly, which is occupied in the recent state by the anterior end of the kidney and the branches of the vagus nerve. From the upper margin a process projects internally, which articulates with the epiotic. The pterotic articulates with the whole upper margin of the bone, and with the front of the above-mentioned process. In front it articulates with the prootic, and below with the basioccipital, and slightly with the parasphenoid. The posterior margin bends slightly inwards, and articulates with the exoccipital (which also joins the lower edge of the epiotic process). The upper limb of the notch supports on its inner surface the external limb of the post-temporal. Near the junction of the upper and anterior borders the bone is perforated by a foramen for the glosso-pharyngeal nerve. The cerebral surface is applied against the labyrinth, especially the external semi-circular canal.

The pterotic forms the greater part of the lateral ridge or parotic process of the skull. Its outer surface is excavated, affording origin to a group of muscles, which raises the gills. In front it articulates with the sphenotic and prootic bones, which complete, with it, the articular cavity for the hyomandibular, in the formation of which the pterotic takes the largest share. Below it articulates with the opisthotic. It overlaps the sphenotic on the upper surface of the skull, but is overlapped by the latter bone on the lateral surface. It also articulates on the roof of the skull with the epiotic and parietal, and presents a thin ridge,² which forms a backward continuation of the outer ridge of the frontal. Its cerebral surface forms a bony ring around the external semi-circular canal. In front of this a process, going downwards and forwards, meets an ascending process of the prootic. This forms another ring around the anterior vertical semicircular canal and front of the vestibule, and the space in which they lie is closed above by the sphenotic.

¹ The otoliths are not described here, as they belong more properly to the anatomy of the ear than to general osteology.

² Spoken of above as the "inner ridge of the pterotic."

The sphenotic continues the parotic ridge forwards. It unites behind with the pterotic; above and behind, with the parietal; above and in front, with the frontal; and below and in front, with the alisphenoid. The sphenotic is often called "post-frontal"; but the post-frontal is a membrane bone, while the sphenotic is pre-formed in cartilage.¹

The alisphenoid is the smallest of the cranial bones, and is of an irregularly quadrilateral form. The upper edge unites with the frontal; the posterior² with the sphenotic; the lower with the prootic. The anterior or free edge shows a groove, in which the nasal branch of the trigeminal nerve runs up to reach the frontal bone. To this edge the membranous interorbital septum is attached.

The prootic presents on its anterior border a deep notch, through which the branches of the trigeminal and facial nerves pass out of the cranium. It unites below with its fellow of the opposite side, and below this with the parasphenoid, the three bones bounding a deep pit, which is open anteriorly, and gives origin to the recti muscles of the orbit. It articulates above with the alisphenoid, sphenotic, and pterotic, and behind with the opisthotic. It covers the anterior portion of the vestibule and the anterior semi-circular canal. Behind it articulates with the basioccipital in the manner described below.

The basioccipital presents posteriorly a concave articular surface for the atlas, which differs from the articulation of an ordinary vertebra only in being bevelled slightly above. Just above this it articulates with the exoccipitals, and in front and below this articulation it unites with the opisthotics. Mesially below, a tapering wedge of bone stretches forwards, and fits in between two similarly shaped processes of the parasphenoid, which, passing backwards, fit into grooves on each side of the basioccipital wedge. Viewed from above, the bone shows a pair of deep excavations, separated by a median ridge, the anterior truncated extremity of which articulates with both prootics, which also articulate with the anterior edge of the bone external to this. These sutures are not seen

¹ A post-frontal and sphenotic may co-exist, as in *Amia* (Macalister, *Morphology of Vertebrate Animals*, p. 72).

² More properly, postero-external.

on the outside of the skull, being concealed by the opisthotics and parasphenoid.

The mesethmoid¹ consists of a pyramid-shaped portion and a process, which stretches backwards from this to articulate with the frontal. The base of the pyramid rests on cartilage, which separates it from the vomer and prefrontals. The *bone*, however, touches the vomer in front, and two processes behind bridge over the cartilage and join the prefrontals. From the apex of the pyramid strong ligaments pass downwards and outwards to the maxillas, and the maxilla articulates with a cavity formed by the mesethmoid and vomer and the cartilage between them.

The vomer, viewed from below, is shaped something like an arrow-head, the barbs pointing backwards. In front there are a few teeth attached to this (the under) surface. Above it articulates with the mesethmoid, prefrontal, and parasphenoid, and, curving round the anterior end of the latter bone, articulates with it also below. At the side, close behind the barbs of the arrow, is a depression for the attachment of a very strong ligament, which connects it to the palate bone.

The parasphenoid is a long, strong bone, stretching along nearly the entire length of the base of the skull. In the middle it is somewhat constricted, and of a prismatic form. In front of this its upper margin splits, to enclose the median cartilage, and the anterior fourth of the bone articulates with the vomer below and prefrontal above. Behind the constricted portion a pair of processes run upwards and outwards, and, articulating with the prootics, bound the pit for the orbital muscles. Behind it articulates with the opisthotics and basioccipital.

The prefrontal is of a very irregular form. Behind it expands into a broad, curved plate, which articulates with the frontal. On the outer edge of this there is a projecting ridge, the truncated end of which articulates with the lacrymal, and below this a ligament connecting it to the entopterygoid is attached. In front of this the bone narrows, and, where it joins the vomer, articulates with the angle of the palate bone. Below a process stretches backwards, articulating with the parasphenoid, and sheathing the side of the median cartilage; and where this process joins the body

¹ Often called simply "ethmoid."

of the bone the two prefrontals unite above the cartilage. In front it joins both vomer and mesethmoid.

The hyomandibular (Pl. VI., fig. 7) presents a head above, a body, and three processes. The head is convex above, compressed from side to side, articulating with a hollow formed by the sphenotic, pterotic, and prootic bones. Below the head is a slightly constricted neck, and below this externally the body spreads out into a nearly smooth triangular surface, into which is inserted a muscle (Pl. VI., fig. 4, *f*), which abducts the whole apparatus (suspensorum and operculum included). The anterior border of the bone is perforated in two places for the anterior and posterior branches of the facial nerve. The anterior process spreads out in a fan-like form, and joins the metapterygoid in front, and just touches the symplectic. Behind it is connected to the symplectic by a triangular piece of cartilage, which articulates with the stylo-hyal. The middle process articulates firmly with the preoperculum, passing external to it. Between these two processes runs a ridge, under which the temporal muscle dips to take additional origin. The posterior process, stretching backwards, furnishes an articular condyle to the operculum proper.

The symplectic is of an elongated, triangular form, with the base above. The latter is connected to the hyomandibular by the triangular intercalary cartilage, and (very slightly) in front of this by bone. The narrow apex fits into a groove in the inner surface of the quadrate. The anterior border fits into a longitudinal groove on the posterior border of the metapterygoid, and the posterior border bounds anteriorly a large fenestra (Pl. VI., fig. 5, *d*), through which the anterior branch of the facial nerve passes.

The quadrate furnishes an articular condyle to the mandible below, which is concave from side to side, and convex from before backwards. From this runs a strong ridge backwards and upwards, the postero-inferior edge of which is firmly united to the preoperculum, which slightly overlaps it. On the inner surface is the groove for the symplectic. Anteriorly a comparatively thin scale of bone springs from the ridge, and is grooved in front for the ectopterygoid, and above for the metapterygoid.

The metapterygoid is a splint of bone, resembling the symplectic, but smaller, more slender, with the base downwards, and slightly curved, with the concavity outwards. The posterior border

is grooved for the symplectic and anterior process of the hyomandibular. The base articulates with the quadrate, and in front it touches the ectopterygoid.

The ectopterygoid is a splint of bone, somewhat expanded behind, where it articulates with the quadrate. A small strip of cartilage persists between the two bones. In front it articulates with the palate; above and internally, with the entopterygoid. Its postero-superior angle articulates with a small portion of the metapterygoid, the latter overlapping it externally.

The entopterygoid is a nearly flat, ovate-oblong scale of bone, the broader end being anterior. It lies on a plane internal to the ectopterygoid, to which it articulates by its lower edge. In front it joins the palate. Behind it tapers to a blunt point, which does not quite reach the metapterygoid. From the anterior end above and from the cartilage in front of this, a strong ligament passes to the prefrontal, being attached to a point below the lachrymal articulation.

The palate bone consists of an irregularly quadrilateral plate or body behind, and a sub-cylindrical process in front. The process does not continue the axis of the body, but bends downwards and slightly outwards. Its anterior end articulates with the upper end of the maxilla, and the lower surface of the lachrymal slides over it above. From its upper border, where it joins the body, a strong ligament connects it to the apex of the anterior superior process of the premaxilla of the opposite side. Just behind and internal to this it is excavated, to articulate with a cartilaginous eminence on the junction of the prefrontal and vomer. It articulates behind with the ento- and ecto-ptyerygoids—with the former above and internally, the line of union being straight, and partly occupied by cartilage; and with the latter below and externally, by a splintery, serrated suture. From the inner side of the anterior part of the body a strong ligament is given off to a groove in the side of the anterior end of the vomer.

In front of the ethmoid is a piece of cartilage which supports the maxilla and premaxilla: it will be spoken of as the pre-ethmoid cartilage for convenience of reference.¹

¹ I have not met with any name for it in the English text-books. Cuvier (*Leçons d'Anatomie Comparée*, vol. ii., page 652) calls it "un cartilage sphérique sur lequel

The pre-ethmoid cartilage is of a nodular form, slightly flattened from side to side, convex above, the convexity being interrupted by a groove behind, where the palato-premaxillary suture crosses it. The premaxillæ and maxillæ articulate with the front and sides. Posteriorly it presents a deep groove, which is on the sharp anterior edge of the ethmoid. Above it is overlapped by the nasal bones. It is connected to the maxillæ and premaxillæ by ligaments, and by weak ligamentous fibres to the nasals and ethmoid.

The premaxilla (Pl. VII., fig. 9) is a small, curved bone, bearing a process on its lower surface. Superiorly, it presents two processes; inferiorly, one. The anterior superior process presents a groove (Pl. VII., fig. 9, 4) on its inner surface, which affords attachment to a ligamentous substance, connecting it to its fellow of the opposite side. Just behind this (2) it articulates with the pre-ethmoid cartilage, and, behind the articulation (3), a ligament connects it to the cartilage. From the apex (1) passes a strong ligament to the palate bone of the opposite side. The posterior superior process presents postero-internally a little condyle (5), which articulates with the maxilla, a bi-concave disk of fibro-cartilage being interposed. The inferior process (7) slides on the inner side of the maxilla, and keeps the premaxilla from displacement outwards, especially when the mouth is closed. From the inner side of the upper end (6) a ligament passes backwards to the maxilla, and from the lower end a weak ligament passes to join the anterior maxillo-mandibular ligament.

The maxilla (Pl. VII., fig. 10) is a rather slender, slightly curved bone, flattened (*i.e.* compressed from side to side) below, the upper end presenting posteriorly a convex articular head (fig. 10, 4), and anteriorly two processes—an external and an internal. The head articulates with a deep pit, formed by the ethmoid and vomer and the cartilage between them, an interarticular fibro-cartilage being interposed. The internal process gives attachment to a ligament (2) going to the pre-ethmoid cartilage. Anteriorly it articulates with the premaxilla (6), and gives attachment to the premaxillo-maxillary ligament (1), and just below this presents a little spur.

s'opère le mouvement de la mâchoire," and Meckel (*Anatomie Comparée*, French edition, vol. ii., page 500) calls it "un cartilage articulaire, triangulaire."

A rheotome at the home station puts the wire leading to e, e for a moment into circuit with a battery.¹ If the platinum wire p is in its highest position, as it should be, and hence in contact with n , the current will, during the first instant, return by the wire common to n and to the thermometer—*i.e.* by wire No. III. This fact is known at the home station by the deflection of a galvanometer in circuit with wire No. III. The magnet e, e , however, immediately attracts up an armature attached to the arm i . This arm is hinged at one extremity; at the other it carries a smooth steel pallet, x . The pallet, on moving forward, engages with one of the triangular teeth, turning the wheel through such a distance that a second pallet, g , just gets over another of the teeth, and, on the current being turned off, and the first pallet being restored to its neutral position by the agency of the spring 2, completes the turning of the wheel through one tooth. One make and break, then, of the rheotome serves to turn the wheel and screw by $\frac{1}{20}$ th of a revolution (as there are twenty teeth provided). The screw, however, has a pitch of $\frac{1}{10}$ th of an inch; hence a motion downwards of $\frac{1}{200}$ th of an inch has been imparted to the wire p . The weight P has also been raised through a certain distance. A second make and break of the rheotome urges the wire downwards by another $\frac{1}{200}$ th of an inch; and so on. Ultimately, when the wire reaches the mercury in the thermometer, a second deflection of the galvanometer on wire No. III. in the home station takes place. The number of contacts made is read on the rheotome, and the height of the thermometer deduced.

Contact is now made for a few seconds between wire No. II. and the battery. The effect on the instrument is, that by the motion of the arm i towards the electro-magnet e', e' , the pallet x , moving backwards, lifts the second pallet, g , out of the wheel, and so liberates the wheel to the action of the weight P . The limb f and wire p are consequently run up to their highest positions, on attaining which a deflection of the galvanometer once more occurs, and the observer in the home station breaks contact.

The object of having the wire p hung loosely on the arm f , instead of having it firmly attached to it, is probably apparent.

¹ If the instrument be very far removed from the home station, a relay to supply the necessary current to the electro-magnets will be required.

In the latter case, if failure of proper contact between the wire and the mercury occurred, the observer might damage the thermometer by urging the wire below the surface of the mercury. As arranged, the wire, under such circumstances, would merely rest on the surface of the mercury, however far f was urged downwards.

The weight P might perhaps with advantage be dispensed with in favour of a spring coiled in a drum fixed on w' . With the dimensions shown, this spring would be subject to five turns during the complete descent of the wire.

This arrangement, being of a purely mechanical type, admits of many variations. One form has been made for me by Mr. Yeates, in which the elevation of the wire is effected by rotating the toothed wheel in the opposite direction by the second electromagnet. The contrivance for effecting this is due to Mr. Yeates. In this case the screw itself advances downwards or upwards, carrying the platinum wire attached to its extremity. The screw bites in a nut borne by the toothed wheel, but is held from turning with it, being slotted longitudinally, a fixed pin projecting into the slot. Such a form, although found to work very satisfactorily, has the great disadvantage of requiring as many makes and breaks of circuit to lift the wire out of the thermometer as to take the reading in the first instance. The quick return in the present arrangement does away with this objection.¹

It will be noticed that three wires are needed to work the instrument—one to each magnet—that is, one to lower the movable wire, and one to raise it, a third being necessary to notify the position of the wire, whether in contact with the starting-point contact or with the mercury contact. Now, it will be obvious that this third wire might be common to any number of instruments contained in an observatory, and the second wire might be dispensed with by the addition to each instrument of an arrangement

¹ The instrument constructed for me reads to the $\frac{1}{40}$ th of a degree Fahrenheit. This delicacy is unnecessary, and has the disadvantage of making reading a slow and tedious operation. Its certainty of action is all that could be desired. In the form proposed above a delicacy of $\frac{1}{8}$ th of a degree Centigrade is intended, each degree causing a rise of about $\frac{1}{40}$ th of an inch in the mercury.

A little glycerine is placed over the column of mercury in the thermometer, to exclude air bubbles.

for automatically shunting the current from the electro-magnets e, e to the electro-magnets e', e' on contact being made with the mercury, or on *complete* descent of the wire. In any case, as described, the number of wires making up the cable going to the observatory would not, for n instruments, exceed $2n + 1$.

Any number of instruments, however, may, I venture to think, be worked with perfect reliability and certainty by the use of three wires only. Plate IV. will show how this is accomplished, the only extra piece of apparatus needed being a disc,¹ carrying insulated contact pieces arranged round its circumference. To these the wires, &c., of the different instruments are attached. Of the three needful wires, then, I. serves to put one after the other of the contacts into circuit with the home station through wire II. By this second wire the readings are taken and the readjustment of the instruments effected. The arrangement by which the current through I. puts the wire II. in communication successively with the several contacts will be understood from the figure and from the foregoing description of a similar mechanical contrivance in the case of the thermometer. Wire III. for indication of the contacts, is taken from all the instruments to the galvanometer in the home station.

One of the wires in the observatory is shown on the diagram as a "test wire." When the movable hand arrives at the contact piece attached to this wire, the current on I. returns through II. to the home station. If, therefore, at any time a check on the position of the hand of the distributor in reference to the indications of the commutator at the home station is desired, it is only necessary to work the commutator, II. being put in connexion with the galvanometer.

The operations involved in taking a reading are obvious. The commutator is first worked till the required instrument is in circuit—that is, the hand of the commutator is put over the *first* contact devoted to that instrument. The rheotome on wire II. is now brought into action. In starting it, a deflection of the galvanometer on III. shows that the contacts are being truly reckoned from the zero point of the distant instrument. The hand of the rheotome is now steadily turned till a second deflection of the

² Plate IV. is diagrammatic only.

galvanometer shows that the descending wire in the instrument has reached the mercury level. The rheotome is provided with a counter, on which the number of contacts is recorded. Reference to a Table gives at sight the reading of the instrument. This being recorded, the commutator hand is moved over the next contact, *i.e.* the *second* devoted to the instrument in question. The current through the rheotome has now been shunted at the instrument; the galvanometer for a moment returns to its zero position, but is immediately deflected again by the readjustment of the instrument into contact with wire III. In the interval the movable limb of the distant instrument has returned to its starting-point.

These operations being consecutive and of a purely mechanical nature, it will be evident that a clockwork arrangement, to take automatically the readings of the various instruments and record them on divided paper, need not be very complicated or expensive. It will suffice to indicate briefly the nature of such an arrangement.

A drum bearing divided paper is provided with a metallic stud at one extremity. This stud moves over the disc of the commutator, shown in Plate IV. as attached to wire I. Intermittent motion is imparted to the drum through a suitable cam. The intervals of rest are alternately long and short. That is, at a *reading* contact it halts, say, for two minutes, the reading being taken and recorded on the drum; it moves forward, resting for, say, thirty seconds at the succeeding contact piece, while the instrument which has just been read is being restored to its zero position. Its next halt is again for two minutes, when another instrument will be in circuit; and so on, the paper on the drum being divided into longitudinal divisions for the separate record of each succeeding instrument.

Parallel to the axis of the drum, and attached axially to the movable arm of the rheotome (on wire II.), a spindle carrying a screw thread revolves. The screw may be a fac-simile or an enlargement of those on the distant instruments. A carriage, with small pricker attached, moves on the screw. Separate clockwork may work the rheotome, but gearing with the commutator is provided, so that, on the drum coming to rest over a contact, the

rheotome is started, and continues making and breaking circuit on wire II., moving the carriage and pricker at the same time longitudinally in front of the drum. When, after a certain number of contacts, the current returns by wire III., a small electro-magnet comes into action, which is so arranged as to throw the rheotome out of gear, and simultaneously press the pricker forward on the paper carrying the drum. The reading is now recorded on the drum. The next movement of the drum to the succeeding contact allows of the adjustment of the distant instrument, and also of the carriage carrying the pricker.

In conclusion, the following suggestions as to the forms which might be given to some of the instruments may not be out of place.

In the case of the barometer, the siphon form of the instrument would be used, probably with wide vacuum chamber and narrow air surface. The thermometer, wet bulb thermometer, solar radiation thermometer, and terrestrial radiation thermometer, are suitable, as already described, with such modifications as the free and uninfluenced readings of the instruments in their several positions demand. For the rain-gauge I would suggest the following arrangement:—

The rain, collected in a suitable vessel, is conducted into a vertical cylinder, which forms the longer branch of a U tube. This tube contains mercury, the level of which in the shorter limb is read in ascertaining the rainfall. The height to which the mercury would be raised for a given fall of rain on a given receiving surface is a question of the relative diameters of the two branches. The receiving surface being eight inches in diameter, it is easy to adopt such a diameter for the containing vessel that the pressure due to one inch of rainfall, say, since last reading, shall be represented by some three or four inches rise of the mercury. For the purpose of emptying the water-vessel after each reading, an electro-magnet is arranged to open a valve at the base of the vessel. The current to this electro-magnet is interrupted automatically when the water has fallen to a certain zero level. This is effected by passing it through the mercury column in the short limb of the tube, the fall of the mercury breaking the circuit at the desired point.

Wind velocity, if treated by a Robinson's anemometer, might be converted into and read as a vertical movement by an arrangement like that described by Professor Perry (*Practical Mechanics*, p. 241). Wind pressure would be more easily dealt with.

An anemoscope would also be needed. This might consist of a disc, traversed by a metallic sector, attached to an exposed vane, the position of the sector, and so the direction of the wind, being ascertained by successive contacts.

XXI.—THE OSTEOLOGY AND ARTHROLOGY OF THE HAD-
DOCK (*GADUS AEGLEFINUS*). BY H. ST. JOHN
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municated by ALEXANDER MACALISTER, M. D., F. R. S.]

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IN this Paper is given a detailed description of the osteology and arthrology of a single type of Teleostean fish. In a work of this kind there is not likely to be found anything new, although several things in it are new to me, such as the existence of a cartilaginous rod passing from the atlas into the exoccipital bone, the peculiarity of the articulation of the first rib, the existence of a structure which is probably the homologue of the lower labial cartilage of the Elasmobranch fish, &c.

It will be convenient to adopt the usual classification of the vertebrate skeleton into *axial* and *appendicular* parts—the former comprising the skull and vertebral column; the latter, the shoulder and pelvic girdles, with the bony axes of the limbs: to these may be added, in fishes, the interspinous bones and fin-rays.

The skull may be divided into the cranium, or brain-case, and the bones of the face, the latter including the suspensorium and gill arches and the operculum, or gill cover.

The cranium is composed of the following bones: the supra-occipital, frontal, and mesethmoid form the roof from behind forwards in the middle line; more laterally, the parietal, epiotic, pterotic, and sphenotic, the two latter appearing also in the lateral walls, and the epiotic in the posterior wall; laterally the skull is bounded by the pterotic, opisthotic, sphenotic, prootic, alisphenoid, and prefrontal or ectethmoid; posteriorly by the supraoccipital, epiotic, exoccipital, and small parts of opisthotic and basioccipital (see Pl. V., figs. 1, 2, and 3). The floor is formed by the basioccipital, prootic, and prefrontal, and is closed below the middle portion by a membranous interorbital septum.

If the fresh head be boiled for a short time, all but two of the facial bones (the parasphenoid and vomer) will become detached. These two bones will remain strongly connected to the brain-case, but are not included among the bones of the cranium, as the prootic bends inwards, and articulates with its fellow of the opposite side above the parasphenoid, thus entirely excluding the latter bone. The prefrontals in the same way exclude the vomer. The mesethmoid and prefrontal do not appear at first sight to form parts of the brain-case, but it will be remembered that the olfactory nerves pass out between the frontal and prefrontal, and end in the olfactory bulbs (Pl. VII., fig. 13, 3), which are morphologically part of the brain. These bulbs lie on the prefrontal, in a hollow bounded by the mesethmoid in front, partly roofed by the same, and bounded laterally by membrane. From between the mesethmoid and prefrontal a strong rod of cartilage projects backwards above the parasphenoid and vomer; the membranous interorbital septum splits to enclose this, and is attached to the parasphenoid below.

The hyomandibular, with the symplectic and quadrate, forms the suspensorium. The quadrate, connected to the palate by the three pterygoids, forms, with these bones, the palato-quadrate arch. Thus, from the palate to the hyomandibular there is an immovably articulated chain of bones (Pl. VI., fig. 5), which is strengthened by a strong splint, the preoperculum, which is united by suture to the quadrate and hyomandibular. This arch articulates in two places with the skull; the head of the hyomandibular with a cavity formed by the pterotic, prootic, and sphenotic bones; and the angle of the palate bone with a cartilaginous eminence developed on the junction of the prefrontal and vomer. It is also suspended to the anterior end of the skull by strong ligaments. The quadrate furnishes an articular condyle to the mandible.

The orbit is bounded above by the frontal and prefrontal. To the side of the latter is articulated a rather large lachrymal, to the back of which is attached a chain of five small suborbital bones, the last of which articulates with a projecting angle of the frontal, thus surrounding the orbit with a bony ring. The lachrymal projects forwards in front of the orbit, overlapping the upper ends of the maxilla and premaxilla, and its internal edge is joined by ligamentous fibres to the nasal, the inner edge of which is connected in a similar way to the ethmoid. The posterior portion of

the nasal bone overlies the nasal sacs. Other facial bones are the maxilla and premaxilla, and, connecting the skull with the shoulder girdle, is a forked post-temporal bone, from the concavity of which three small scales of bone pass to the inner, and one to the outer, ridge of the pterotic bone. Before passing to the hyoid apparatus and gills, a more particular description may be given of the above-mentioned bones.

The frontal is the largest bone in the skull, and consists of two lateral halves fused. From the back of the upper surface projects an elevated ridge, which is continuous with the crest of the supraoccipital, the latter being wedged into a deep groove behind it. At the sides of this are a pair of ridges, continuous with the inner ridges of the pterotics. These ridges are undermined from the outer side by deep grooves, which lodge mucous glandular tissue in the recent state. They communicate with a pair of curious oval apertures, which lie in front of the central ridge. Laterally the bone projects over the orbit, forming its roof. On the under surface are seen two curved ridges, the anterior ends of which articulate with the prefrontals, and the posterior with the alisphenoids. Just external to the articulation with the prefrontal is a groove, through which the nasal branch of the trigeminal nerve passes, and external to this the bone again articulates with the prefrontal. Stretching forwards over the latter, the frontal articulates with the ethmoid. Posteriorly it articulates with the sphenotic, parietal, and supraoccipital, and only just touches the inner ridge of the pterotic. The frontal overlaps every bone with which it articulates.

The supraoccipital consists of a large elevated crest, continuous with the median ridge of the frontal, and of two small lateral portions. These articulate with the epiotics externally, and the articulations are overlapped by the parietals, which also articulate with the supraoccipital farther in front. The under surface of the crest articulates below with the exoccipitals, and the latter, uniting together, exclude the supraoccipital from the foramen magnum; in front it articulates with the frontal. The back of the crest is closely connected by ligamentous fibres to the neural spine of the atlas.

The parietal is a curved scale of bone, presenting a well-marked ridge, which runs from before backwards, with an inclination out-

wards. Just below this ridge it is perforated for a branch of the trigeminal nerve. It overlaps all the bones of the cranium with which it articulates, except the frontal. If the skull be softened in boiling water, it can be easily raised without disturbing the other bones. It is then seen to bridge over the hiatus¹ between the supraoccipital and pterotic bones, both of which it overlaps for some distance. It articulates also with the epiotic, sphenotic, frontal, and just touches the alisphenoid. The tip of the inner limb of the post-temporal fits into a groove on the upper surface behind.

The epiotic is a very small bone, presenting a superior and an external surface, placed at right angles to each other, and a narrow posterior surface; above it articulates with the parietal, and just behind this supports the inner limb of the post-temporal; internally it joins the supraoccipital; below, the exoccipital, and externally the pterotic and opisthotic. Its cerebral surface is excavated by the posterior vertical semicircular canal.

The exoccipital (Pl. VI., fig. 6) presents on its posterior surface a convexity from side to side, and a concavity from above downwards. The convexity forms a ridge, which is bent in such a manner as to present a concavity outwards, which overhangs a large foramen in the upper end of the bone for the vagus nerve. Below, the ridge ends in a sub-cylindrical extremity, which articulates with a process of the body of the atlas. Internal to the ridge, near where it joins the atlas, is a foramen for the first spinal nerve. The two exoccipitals, with the basioccipital, bound the foramen magnum. The inner borders articulate above with the supraoccipital; below,² with each other. The sutures seen on the outside of the skull are with the supraoccipital, epiotic, opisthotic, and basioccipital. The outer portion of the bone stretches forwards on the inner surface of the opisthotic (inside the skull), and is connected to the prootic and pterotic by a strip of cartilage. The upper part of the cerebral surface of the bone is notched by the lower crus of the posterior vertical semicircular canal; and just below the internal opening of the foramen for the vagus nerve is a slender, foot-like process, which, articulating with a ridge on the upper surface of the basi-

¹ This space is also closed partially by cartilage, which underlies the parietal.

² That is, by the edges of the surface which is turned towards the commencement of the spinal cord.

occipital, forms a bony hoop, which supports the large otolith, being applied against the posterior end of its inner convex surface.¹

The opisthotic is a thin bone, which is bent in such a manner as to present a notch posteriorly, which is occupied in the recent state by the anterior end of the kidney and the branches of the vagus nerve. From the upper margin a process projects internally, which articulates with the epiotic. The pterotic articulates with the whole upper margin of the bone, and with the front of the above-mentioned process. In front it articulates with the prootic, and below with the basioccipital, and slightly with the parasphenoid. The posterior margin bends slightly inwards, and articulates with the exoccipital (which also joins the lower edge of the epiotic process). The upper limb of the notch supports on its inner surface the external limb of the post-temporal. Near the junction of the upper and anterior borders the bone is perforated by a foramen for the glosso-pharyngeal nerve. The cerebral surface is applied against the labyrinth, especially the external semi-circular canal.

The pterotic forms the greater part of the lateral ridge or parotic process of the skull. Its outer surface is excavated, affording origin to a group of muscles, which raises the gills. In front it articulates with the sphenotic and prootic bones, which complete, with it, the articular cavity for the hyomandibular, in the formation of which the pterotic takes the largest share. Below it articulates with the opisthotic. It overlaps the sphenotic on the upper surface of the skull, but is overlapped by the latter bone on the lateral surface. It also articulates on the roof of the skull with the epiotic and parietal, and presents a thin ridge,² which forms a backward continuation of the outer ridge of the frontal. Its cerebral surface forms a bony ring around the external semi-circular canal. In front of this a process, going downwards and forwards, meets an ascending process of the prootic. This forms another ring around the anterior vertical semicircular canal and front of the vestibule, and the space in which they lie is closed above by the sphenotic.

¹ The otoliths are not described here, as they belong more properly to the anatomy of the ear than to general osteology.

² Spoken of above as the "inner ridge of the pterotic."

The sphenotic continues the parotic ridge forwards. It unites behind with the pterotic; above and behind, with the parietal; above and in front, with the frontal; and below and in front, with the alisphenoid. The sphenotic is often called "post-frontal"; but the post-frontal is a membrane bone, while the sphenotic is pre-formed in cartilage.¹

The alisphenoid is the smallest of the cranial bones, and is of an irregularly quadrilateral form. The upper edge unites with the frontal; the posterior² with the sphenotic; the lower with the prootic. The anterior or free edge shows a groove, in which the nasal branch of the trigeminal nerve runs up to reach the frontal bone. To this edge the membranous interorbital septum is attached.

The prootic presents on its anterior border a deep notch, through which the branches of the trigeminal and facial nerves pass out of the cranium. It unites below with its fellow of the opposite side, and below this with the parasphenoid, the three bones bounding a deep pit, which is open anteriorly, and gives origin to the recti muscles of the orbit. It articulates above with the alisphenoid, sphenotic, and pterotic, and behind with the opisthotic. It covers the anterior portion of the vestibule and the anterior semi-circular canal. Behind it articulates with the basioccipital in the manner described below.

The basioccipital presents posteriorly a concave articular surface for the atlas, which differs from the articulation of an ordinary vertebra only in being bevelled slightly above. Just above this it articulates with the exoccipitals, and in front and below this articulation it unites with the opisthotics. Mesially below, a tapering wedge of bone stretches forwards, and fits in between two similarly shaped processes of the parasphenoid, which, passing backwards, fit into grooves on each side of the basioccipital wedge. Viewed from above, the bone shows a pair of deep excavations, separated by a median ridge, the anterior truncated extremity of which articulates with both prootics, which also articulate with the anterior edge of the bone external to this. These sutures are not seen

¹ A post-frontal and sphenotic may co-exist, as in *Amia* (Macalister, *Morphology of Vertebrate Animals*, p. 72).

² More properly, postero-external.

on the outside of the skull, being concealed by the opisthotics and parasphenoid.

The mesethmoid¹ consists of a pyramid-shaped portion and a process, which stretches backwards from this to articulate with the frontal. The base of the pyramid rests on cartilage, which separates it from the vomer and prefrontals. The bone, however, touches the vomer in front, and two processes behind bridge over the cartilage and join the prefrontals. From the apex of the pyramid strong ligaments pass downwards and outwards to the maxillas, and the maxilla articulates with a cavity formed by the mesethmoid and vomer and the cartilage between them.

The vomer, viewed from below, is shaped something like an arrow-head, the barbs pointing backwards. In front there are a few teeth attached to this (the under) surface. Above it articulates with the mesethmoid, prefrontal, and parasphenoid, and, curving round the anterior end of the latter bone, articulates with it also below. At the side, close behind the barbs of the arrow, is a depression for the attachment of a very strong ligament, which connects it to the palate bone.

The parasphenoid is a long, strong bone, stretching along nearly the entire length of the base of the skull. In the middle it is somewhat constricted, and of a prismatic form. In front of this its upper margin splits, to enclose the median cartilage, and the anterior fourth of the bone articulates with the vomer below and prefrontal above. Behind the constricted portion a pair of processes run upwards and outwards, and, articulating with the prootics, bound the pit for the orbital muscles. Behind it articulates with the opisthotics and basioccipital.

The prefrontal is of a very irregular form. Behind it expands into a broad, curved plate, which articulates with the frontal. On the outer edge of this there is a projecting ridge, the truncated end of which articulates with the lacrymal, and below this a ligament connecting it to the entopterygoid is attached. In front of this the bone narrows, and, where it joins the vomer, articulates with the angle of the palate bone. Below a process stretches backwards, articulating with the parasphenoid, and sheathing the side of the median cartilage; and where this process joins the body

¹ Often called simply "ethmoid."

of the bone the two prefrontals unite above the cartilage. In front it joins both vomer and mesethmoid.

The hyomandibular (Pl. VI., fig. 7) presents a head above, a body, and three processes. The head is convex above, compressed from side to side, articulating with a hollow formed by the sphenotic, pterotic, and prootic bones. Below the head is a slightly constricted neck, and below this externally the body spreads out into a nearly smooth triangular surface, into which is inserted a muscle (Pl. VI., fig. 4, *f*), which abducts the whole apparatus (suspensorum and operculum included). The anterior border of the bone is perforated in two places for the anterior and posterior branches of the facial nerve. The anterior process spreads out in a fan-like form, and joins the metapterygoid in front, and just touches the symplectic. Behind it is connected to the symplectic by a triangular piece of cartilage, which articulates with the stylo-hyal. The middle process articulates firmly with the preoperculum, passing external to it. Between these two processes runs a ridge, under which the temporal muscle dips to take additional origin. The posterior process, stretching backwards, furnishes an articular condyle to the operculum proper.

The symplectic is of an elongated, triangular form, with the base above. The latter is connected to the hyomandibular by the triangular intercalary cartilage, and (very slightly) in front of this by bone. The narrow apex fits into a groove in the inner surface of the quadrate. The anterior border fits into a longitudinal groove on the posterior border of the metapterygoid, and the posterior border bounds anteriorly a large fenestra (Pl. VI., fig. 5, *d*), through which the anterior branch of the facial nerve passes.

The quadrate furnishes an articular condyle to the mandible below, which is concave from side to side, and convex from before backwards. From this runs a strong ridge backwards and upwards, the postero-inferior edge of which is firmly united to the preoperculum, which slightly overlaps it. On the inner surface is the groove for the symplectic. Anteriorly a comparatively thin scale of bone springs from the ridge, and is grooved in front for the ectopterygoid, and above for the metapterygoid.

The metapterygoid is a splint of bone, resembling the symplectic, but smaller, more slender, with the base downwards, and slightly curved, with the concavity outwards. The posterior border

is grooved for the symplectic and anterior process of the hyomandibular. The base articulates with the quadrate, and in front it touches the ectopterygoid.

The ectopterygoid is a splint of bone, somewhat expanded behind, where it articulates with the quadrate. A small strip of cartilage persists between the two bones. In front it articulates with the palate; above and internally, with the entopterygoid. Its postero-superior angle articulates with a small portion of the metapterygoid, the latter overlapping it externally.

The entopterygoid is a nearly flat, ovate-oblong scale of bone, the broader end being anterior. It lies on a plane internal to the ectopterygoid, to which it articulates by its lower edge. In front it joins the palate. Behind it tapers to a blunt point, which does not quite reach the metapterygoid. From the anterior end above and from the cartilage in front of this, a strong ligament passes to the prefrontal, being attached to a point below the lachrymal articulation.

The palate bone consists of an irregularly quadrilateral plate or body behind, and a sub-cylindrical process in front. The process does not continue the axis of the body, but bends downwards and slightly outwards. Its anterior end articulates with the upper end of the maxilla, and the lower surface of the lachrymal slides over it above. From its upper border, where it joins the body, a strong ligament connects it to the apex of the anterior superior process of the premaxilla of the opposite side. Just behind and internal to this it is excavated, to articulate with a cartilaginous eminence on the junction of the prefrontal and vomer. It articulates behind with the ento- and ecto-ptyerygoids—with the former above and internally, the line of union being straight, and partly occupied by cartilage; and with the latter below and externally, by a splintery, serrated suture. From the inner side of the anterior part of the body a strong ligament is given off to a groove in the side of the anterior end of the vomer.

In front of the ethmoid is a piece of cartilage which supports the maxilla and premaxilla: it will be spoken of as the pre-ethmoid cartilage for convenience of reference.¹

¹ I have not met with any name for it in the English text-books. Cuvier (*Leçons d'Anatomie Comparée*, vol. ii., page 652) calls it "un cartilage sphérique sur lequel

The pre-ethmoid cartilage is of a nodular form, slightly flattened from side to side, convex above, the convexity being interrupted by a groove behind, where the palato-premaxillary ligaments cross it. The premaxillæ and maxillæ articulate with its front and sides. Posteriorly it presents a deep groove, which slides on the sharp anterior edge of the ethmoid. Above it is overlapped by the nasal bones. It is connected to the maxillæ and premaxillæ by ligaments, and by weak ligamentous fibres to the nasals and ethmoid.

The premaxilla (Pl. VII., fig. 9) is a small, curved bone, bearing teeth on its lower surface. Superiorly, it presents two processes; and inferiorly, one. The anterior superior process presents a groove (Pl. VII., fig. 9, 4) on its inner surface, which affords attachment to a ligamentous substance, connecting it to its fellow of the opposite side. Just behind this (2) it articulates with the pre-ethmoid cartilage, and, behind the articulation (3), a ligament connects it with the cartilage. From the apex (1) passes a strong ligament to the palate bone of the opposite side. The posterior superior process presents postero-internally a little condyle (5), which articulates with the maxilla, a bi-concave disk of fibro-cartilage being interposed. The inferior process (7) slides on the inner side of the maxilla, and keeps the premaxilla from displacement outwards, especially when the mouth is closed. From the inner side of the upper end (6) a ligament passes backwards to the maxilla, and from the lower end a weak ligament passes to join the anterior maxillo-mandibular ligament.

The maxilla (Pl. VII., fig. 10) is a rather slender, slightly curved bone, flattened (*i.e.* compressed from side to side) below, the upper end presenting posteriorly a convex articular head (fig. 10, 4), and anteriorly two processes—an external and an internal. The head articulates with a deep pit, formed by the ethmoid and vomer and the cartilage between them, an interarticular fibro-cartilage being interposed. The internal process gives attachment to a ligament (2) going to the pre-ethmoid cartilage. Anteriorly it articulates with the premaxilla (6), and gives attachment to the premaxillo-maxillary ligament (1), and just below this presents a little spur.

s'opère le mouvement de la mâchoire," and Meckel (*Anatomie Comparée*, French edition, vol. ii., page 500) calls it "un cartilage articulaire, triangulaire."

(3), into which a muscle¹ is inserted. From the outer surface of the base of the external process (5) a ligament passes to the upper and anterior part of the ethmoid, which is crossed by the palatopremaxillary ligament externally. Between the two processes is a recess, which slides on the pre-ethmoid cartilage. Below the head is a slightly constricted neck, on the postero-external surface of which is a smooth facet (7) for the end of the palate bone, and below this, on the posterior border, the posterior maxillo-mandibular ligament is attached. This passes to the outer side of the os articulare, just in front of the articular cavity of the mandible. From the anterior angle of the lower end (9) the anterior maxillo-mandibular ligament passes to the outer side of the dentary, near the symphysis menti.

The mandible consists of three bones—articular, dentary, and angular.²

The articular presents, on its upper surface posteriorly, an articular cavity for the quadrate, which is concave from before backwards, and slightly convex from side to side. In front of this the bone spreads out into a thin triangular plate. Below and in front of the articular cavity, a process stretches downwards and forwards, forming an angle with the rest of the bone, into which part of the dentary fits externally. Internally, between this process and a ridge which stretches downwards from the back part of the articular cavity, is a deep groove, into which the angular fits. Below the triangular plate is a strong ridge, the lower border of which joins edge to edge with a ridge which runs along the middle of the dentary. On the inner surface of the ridge, near its posterior end, is a projecting tubercle, into which the tendon of the temporal muscle is inserted. From this tubercle a persistent rod of cartilage (Meckel's) extends forwards, lying above and internal to the ridge (which supports it), and, with the anterior extremity of the above-mentioned triangular plate, fits into the hollow of the dentary.

The dentary bears teeth on its upper surface (which opposes the premaxilla). The teeth are all small and curved, the points being bent towards the cavity of the mouth. On the premaxilla there are about eight rows, of twenty to thirty in a row. The

¹ Regarded as the analogue of the masseter by Cuvier. (See Pl. VII., fig. 13.)

² I have looked in vain for a *splénial* ossification.

larger teeth are in the outer series. On the mandible they are not so numerous, and are more uniform in size. The dentary bends inwards in front to join its fellow of the opposite side. The dentigerous edge is continued upwards and backwards into a process, which nearly touches the upper angle of the articular, to which it is bound by ligamentous fibres. A strong ridge runs from before backwards along the middle of the bone, and is connected to the dentigerous border externally by a thin osseous lamella, and internally by a somewhat similar lamella, which, however, extends farther backwards. Into the space between these two scales of bone the articular, with Meckel's cartilage, fits.

The angular is a small, irregular nodule of bone, which unites by suture with the articular in the manner above-mentioned. A strong ligament connects its posterior border with the interoperculum.

The nasal (Pl. VII., fig. 14) is a scale of bone, curved in such a manner as to produce a gutter-like depression on its upper surface, running from before backwards. This is filled with mucous glandular tissue in the recent state. Its internal edge touches its fellow in front. Behind, for a short distance, it is in contact with the ethmoid. The external edge touches the lachrymal, and the anterior end overlies the maxilla and premaxilla. To all these bones, and also to the pre-ethmoid cartilage, it is connected by ligamentous fibres.

The lachrymal (Pl. VI., fig. 4, 4) presents above a stout ridge, which runs parallel to the outer border of the nasal. This splits below into two laminae, of which the external extends the lower down. Its posterior superior angle articulates with the prefrontal.

The suborbitals are five small bones built on the type of the lachrymal; namely, a ridge next the orbit splitting peripherally into two laminae.

The preoperculum (Pl. VI., fig. 5, 8) is another bone of this type, the ridge being in front, curved, with the concavity forwards. The internal lamina (as in the lachrymal and suborbitals) is the larger, and it extends farther backwards than the external. The ridge articulates with the quadrate below, and is overlapped by the middle process of the hyomandibular above. From the middle of the concavity a scale of bone extends upwards and forwards, and is wedged between the anterior and middle processes of the hyo-

mandibular, and also partially overlaps the triangular intercalary cartilage. The upper end of the bone articulates with the posterior process of the hyomandibular. The preoperculum is connected behind and below to the other three bones of the gill-cover.

The interoperculum (Pl. V., fig. 11) is a long, thin bone, connected above with the preoperculum, behind with the suboperculum, and in front with the mandible. Near the posterior end a strong spur of bone projects from the internal surface, in front of which a concave articular surface is formed, which supports the articulation of the stylohyal with the epihyal.

The suboperculum is a curved scale of bone, lying below the operculum proper, which overlaps it. It is also overlapped by the preoperculum and interoperculum, and is connected to these three bones by ligamentous fibres.

The operculum proper is irregularly triangular. The superior angle presents, on its internal surface, an articular cavity for the end of the posterior process of the hyomandibular. The upper border is nearly straight; the anterior, convex; and the inferior, concave. Internally, a groove runs from the articular cavity to the posterior angle for the insertion of a muscle, which adducts the bone (see Pl. V., fig. 12).

The ligaments which have been mentioned above may be recapitulated as follows:—Palato-premaxillary (see Pl. VII., fig. 13), palato-vomerine, ento-pterygoid-prefrontal, maxillo-ethmoidal: these are all very strong. Distinct ligaments also connect the maxilla with the premaxilla, and both these bones with the pre-ethmoid cartilage; ligamentous fibres connect the lachrymals and nasals to all the surrounding bones; in particular, a strong network of fibres binds the two premaxillas together, and passing upwards, covers the anterior ends of the lachrymals and nasals. The pre-ethmoid cartilage is entirely hyaline; so is the strong rod of persistent cartilage,¹ which lies between the ethmoid, vomer, prefrontal, and parasphenoid; the disks of fibro-cartilage between the maxilla and ethmoid, and between the maxilla and premaxilla, are nearly all fibrous tissue on the periphery, and nearly pure hyaline cartilage in the centre. Covering the lachrymal where it articulates with the prefrontal is a substance looking to the naked eye very like

¹ The unossified portion of the cranial trabeculae.

cartilage, but which is a peculiar condensed fibrous tissue. The posterior maxillo-mandibular ligament is a band of white fibrous tissue, into which a small muscle¹ is inserted. The anterior maxillo-mandibular ligament contains a very remarkable structure—it is a rod-like body, attached to the dentary below, and tapering to a point above; in the lower part it consists of fibro-cartilage, containing large, well-developed cartilage cells in a network of white fibres; in the upper part it passes into fibrous tissue. The position of this body is identical with that of the lower labial cartilage in elasmobranchs, the dentary being a membrane ossification covering Meckel's cartilage (which forms the lower jaw in cartilaginous fishes), and from the fact of it containing cartilage it may be the homologue of that structure; in the groove between the premaxilla and its inferior process there is a structure very similar in appearance, the tissue being identical with that of the *upper* part of the lower ligament (containing no cartilage cells). Ligamentous fibres connect the two halves of the mandible together, and the four bones of the operculum are similarly connected; a strong ligament passes from the interoperculum to the angular, and the head of the hyomandibular is kept in place by a capsular ligament. Two other structures, though (strictly speaking) membranes, act somewhat the part of ligaments: these are, the interorbital septum and a membrane which connects the palatoquadrate arch with the skull. The latter membrane is attached to the prootic and parasphenoid, and stretches across to the meta-, ento-, and ecto-pterygoid and palate bones, and forms the floor of the orbit. The interorbital septum consists of two symmetrical laminæ of fibres, which fuse into one in the centre of the structure;² it is attached to the parasphenoid, prootic, alisphenoid, frontal, and prefrontal bones; it closes in the posterior (large) division of the cranium (except at the uppermost part) in front; and is perforated by the optic, motor oculi, pathetic, and abducens nerves, while the trigeminal and facial nerves pass out between it and the prootic bone; below this the two layers fuse, and dipping into the pit for the origin of the recti muscles, are attached along the middle of the upper surface of the parasphenoid: above, the two

¹ Cuvier (*op cit.*, vol. iv., i., p. 172) mentions this as “un muscle carré.”

² Or perhaps a single lamina splitting above and below.

layers are attached to the ridges on the under surface of the frontal bone, and are continued to the prefrontal, and, fusing together below, thus bound a prismatic space between them and the bone, in which the olfactory tracts lie. At its attachment to the parasphenoid and prootic the interorbital septum is continuous with the infraorbital membrane (above described).

The Hyoid and Branchial Arches.—A typical branchial arch consists of four pieces, named, from above downwards, pharyngobranchial, epibranchial, ceratobranchial, and hypobranchial. In some fishes (*e.g.* salmon) the three foremost arches are found nearly in this condition, but in many others the pharyngobranchials, which usually expand and bear teeth, show a great tendency to become distorted and fused together, and to have their articulations displaced: moreover, some of the hypobranchials may be wanting, the most constant of these four bones being the ceratobranchial, which is the only representative of the fifth arch. The hypobranchials are connected in the middle line by a series of small bones, or cartilages, the copulæ, the anterior of which is called the entoglossal, and the posterior the urohyal; the hyoid arch is built on the plan of a branchial arch, but the parts are more numerous, and peculiarly modified to perform different functions. The uppermost part of the arch, the hyomandibular, has been already described; also the symplectic (which forms a sort of link between the hyoid and mandibular arches). The remaining parts are the stylohyal, epihyal, ceratohyal, and two hypohyals. Below the hypohyals is a bone, often passed over unnoticed in text-books, for which the name of basibranchiostegal, applied to it by Parker, is perhaps the most convenient.

The stylohyal (Pl. VII., fig. 15) is a small rod-like bone, which, articulating with the triangular intercalary cartilage above, passes downwards internal to the preoperculum, and articulates with the epihyal; the joint so formed is supported behind by an articular cavity on the inner side of the interoperculum.

The epihyal is a triangular piece of bone, the apex articulating with the stylohyal in a movable joint, and the base immovably with the ceratohyal; it is separated from the latter bone below and externally by a strip of cartilage, but joins it internally by a splintery serrated suture.

The ceratohyal, nearly three times as long as the preceding

bone, is connected to it above and to the two hypohyals below; the union to them is chiefly by the mediation of cartilage. The bone is flattened from side to side, and curved, so as to present a slight concavity upwards and forwards; part of the bone, thinner than the rest, projects downwards and slightly outwards, and is marked with notch-like depressions on the outer surface above, and on the inner below, for the branchiostegal rays; the latter are slender, curved, flattened rods of bone, with a sharp edge on the middle of their convex border: they decrease in size from above downwards; four of them articulate with the outside, and three with the inside of the ceratohyal; their direction is upwards, backwards, and slightly outwards; they support the membranous inner gill-cover, by which they are connected to the inter- and sub-operculum.

The two hypohyals, usually called inner and outer, may, from their position in the haddock, be more appropriately called superior and inferior. The inferior is slightly anterior to the other; they are both small pyramidal bones, the bases of the pyramids being turned outwards; there is a considerable amount of cartilage between them and the ceratohyal, and in this, on the outside, is seen the opening of a canal, which passes downwards and inwards, its inner opening being bounded by the two lower bones, which are notched in this situation. This canal transmits a vessel, conveying arterial blood from the first branchial arch to the pseudobranchia.

The superior hypohyals are the smaller; their apices articulate with the entoglossal cartilage, which keeps them apart. A ridge running along the inner side of the anterior border joins a similar ridge on the inferior hypohyal.

The inferior hypohyals articulate with each other by their apices, which are anterior and internal, and by the anterior half of a ridge on their inner surface behind this; they form the chief support of the tongue.

The basibranchiostegal (Pl. VII., fig. 16, *d*) is a thin, irregularly quadrilateral plate of bone, the upper border being the thickest, slightly grooved, and running into a distinct notch, where it meets the anterior border: from the margins of this notch a pair of strong ligaments pass to the apices of the inferior hypohyals: behind this the bone is connected by ligaments to the superior hypohyals. The anterior border is sharp and distinct, the posterior and inferior

borders very irregular; the so-called sterno-hyoid muscle is inserted into the whole of the side of the bone.

The ceratobranchials of the first three arches are hardly distinguishable from one another; that of the fourth arch, however, may be known by a little spur of bone, which projects downwards and inwards from the lower part of the bone. These four bones are slender, rather long and curved, the convexity being downwards and outwards. Running along the convexity is a deep groove for the branchial vessels and nerves, to the margins of which the gill filaments are attached. On the inner surface are the gill rakers, which form a double row on the first three arches, and a single one on the fourth; the anterior row on the first arch are long and curved, each ending in a single point, which is directed downwards; in all the other rows they are shorter, not curved, and end in five or six bristly points. The ceratobranchials articulate by a very movable joint with the epibranchials above, and somewhat less movably with the hypobranchials below.

The ceratobranchials of the fifth arch are shorter than the rest, and constitute the hypopharyngeal bones. They are much broader than the others; the upper expanded surfaces, which are opposed by the epipharyngeal bones, bear several series of teeth; they are connected by ligamentous fibres, in front, to the ceratobranchials of the fourth arch. The under surfaces show a pair of deep grooves for the attachment of the muscular fibres of the œsophagus. The lower ends are the less pointed, and are connected by ligament to the urohyal.

The epibranchials are four small curved bones, which articulate below with the ceratobranchials, and above with the epipharyngeal bones (pharyngobranchials) in a manner to be presently described.

The anterior is the straightest and the most slender; the two posterior are greatly curved, and provided with processes, which articulate with each other, being connected below the articulation by a ligament.

The first and second hypobranchials are small curved bones, grooved on their lower surface, articulating with the copulæ and with the first and second ceratobranchials. A distinct ligament passes from one to the other a little below the middle, and another ligament connects the second to the anterior process of the third.

The third hypobranchial consists of a broad posterior part, hollowed below, and nearly flat above, and a curved anterior process; this process bends inwards, and is connected by a ligament to its fellow of the opposite side, thus arching over the cardiac aorta, and a large vein, which lies between their processes and the copulæ; they underlie the hypobranchials of the second arch. The inner margins of the broad posterior part join the posterolateral edges of a diamond-shaped ossification of the copulæ. Posteriorly the bone supports the third and fourth ceratobranchials, hence it may represent the third and fourth hypobranchials fused.

The epipharyngeal bones consist of three pieces, which (for convenience) are referred to as *a*, *b*, and *c* (see Pl. VII., fig. 16). They are all concave and irregular above, and convex and denticulate below. They oppose the hypopharyngeal bones, and are suspended to the skull and vertebral column by muscles. The piece *a* is the most anterior, and its long axis runs backwards and inwards; parallel to this axis it articulates with *b* internally; its posterior angle nearly touches *c*; the anterior angle rises into a process, which supports the first epibranchial (fig. 16, 1); near the posterior angle it supports part of the second epibranchial, which forms a double condyle, to articulate with *a* and *b*. The piece *b* is the largest, and is roughly triangular; it articulates with *c* postero-externally, and with *a* externally; on the edge which articulates with *c* is a ridge, 3, which is coated with cartilage, and supports part of the third and fourth epibranchials, which articulate both with it and *c*. The piece *c* is a small oval bone, which articulates with *b*, as above mentioned; the upper surface is concave, the hollow being filled with cartilage, which joins the ridge on *b*, and supports the third and fourth epibranchials.

The ossifications in the copulæ consist of a diamond-shaped piece of bone, ending in a long spicule in front, and a shorter one behind. This bony part supports all the hypobranchials; a slender rod of cartilage underlies the front spicule, and is prolonged forwards between the superior hypohyals, forming the entoglossal. From the posterior spicule a similar piece stretches backwards between the ceratohyals of the fourth arch, articulating with them, and is connected by ligament to the hypopharyngeal bones. This is the urohyal.

The Vertebral Column.—The vertebral column consists of fifty-four vertebræ, twenty of which are abdominal, and thirty-four caudal. Of the abdominal vertebræ, all but the two anterior are provided with ribs, and all but the three anterior with parapophyses. The caudal vertebræ have well-marked hæmal spines. The body of the last vertebra is fused with a triangular plate of bone, the coalesced hypurals.

General Characters of Abdominal Vertebræ.—If a vertebra from about the middle of the series (say the ninth, Pl. VIII., fig. 17) be examined, it will be found to consist of a centrum, which is nearly circular, slightly flattened from above downwards, a long neural spine surmounting the neurapophyses, and a pair of long parapophyses, which support a rib and an epipleural spine. The centrum is amphiœlous, the concavities being marked with concentric striæ of a whiter colour than the rest of the bone. On the under surface is a longitudinal groove for the aorta, bounded on each side by a prominent ridge, and lying somewhat to the right side, in the floor of the groove, are two or three foramina. Outside the ridge is a large depression, and next in order, from the lower part of the side, springs the parapophysis, the base of attachment being strongest in front. Above this a prominent ridge forms a sort of second root to the parapophysis, and the upper part of the side of the bone is honeycombed with large and small foramina. From the upper border of the bone in front springs the neurapophysis, and behind the posterior zygapophysis. Between the two is the “intervertebral” notch for the spinal nerves. The upper part of the body is nearly flat, dotted over with small foramina. The neurapophyses have the form of an elongated triangle. Springing from the body by a comparatively narrow pedicle, they stretch forwards over the posterior zygopophyses of the vertebra in front, articulating with them, and thus forming the anterior zygopophyses. In front of this they nearly touch the neurapophyses of the next vertebra, roofing over the intervertebral foramina. They run directly into the neural spine, to which they are firmly ankylosed, thus bounding the neural canal above. The neural spine is dagger-shaped, being flattened from before backwards; it inclines backwards, continuing the axis of the neurapophyses. The posterior zygapophyses are a pair of chisel-shaped spurs of bone, which receive the anterior zygopophyses between them; the articular

surface slopes backwards, outwards, and slightly upwards. The parapophyses are long, curved, thin plates of bone, which incline downwards and backwards, the tips having a slight inclination inwards. On their upper surfaces a ridge runs from the centrum for about half their length. The lower part of their posterior borders are folded over, as if hemmed. On this posterior border, near the tip, is seen a slight groove for the neck of the rib, and nearly half way to the body of the vertebra a little pit for the head of the epipleural spine.

The first three vertebræ are so peculiar, as to require separate description. In the others we notice the following differences:—Following the transverse processes towards the tail, the inclination is more backwards, and the size slightly diminished; the “hem” at the posterior border becomes unrolled, and the anterior border approximates to it, so that the parapophysis takes the form of an inverted gutter, and in the posterior vertebræ lacks altogether the pit for the epipleural spine. Following them forwards, the inclination in the fourth vertebra (Pl. VIII., fig. 19) is directly outwards; the processes diminish rapidly in size, being very short in the fourth vertebra; the epipleural pit and the notch for the rib approach one another, and become confluent at the sixth vertebra. The groove for the aorta inclines towards the middle line in front, and is nearly median at the fourth vertebra. Followed backwards, it also inclines to the middle line, becoming median about the fourteenth, and behind this it becomes indistinct. The first three vertebræ have no parapophyses, and the posterior zygapophyses have the articular surfaces looking directly upwards (which condition is seen to a less extent in the fourth, fifth, and sixth). Those of the atlas and of the second vertebra are large and prominent. The neurapophyses of the first and second have distinctly less inclination backwards than that of the third or any of the others. The bodies of these three are very short, scarcely more than half the length of the ninth.

The atlas (Pl. VIII., fig. 20) presents a strong neural spine, which is closely connected by ligamentous fibres to the crest of the occipital bone. The neurapophyses expand below into anterior zygapophyses, which are longer and stronger than those of the other vertebræ. These articulate with the upper surface of the articular processes of the exoccipital bone (Pl. VI., fig. 6, 3). Im-

mediately below these, and separated from them by a slit-like depression, are a pair of sub-cylindrical articular processes, which are united very firmly to the ends of those of the exoccipital bone. They are hollow, and contain a core of cartilage,¹ which is continued into the exoccipital. The lower surfaces of these processes articulate with the bevelled upper border of the basioccipital; and below this the joint resembles an ordinary articulation between two vertebræ. On the side of the body, just below the posterior zygapophyses, is a small pit, for the attachment of a ligament passing to the supraclavicle.

The second vertebra presents nothing remarkable, except the shortness of body and absence of parapophyses common to the first three vertebræ.

The third vertebra (Pl. VIII., fig. 21) has a shorter neural spine than either the second or fourth. On the side of the body between the anterior and posterior zygapophyses is a deep pit, with which the head of the first rib movably articulates.

Caudal Vertebrae.—The eighth caudal may be taken as a typical member of the series. The centrum is more perfectly circular than that of an abdominal vertebra, and, owing to the absence of parapophyses, the sides appear more flattened. They are beautifully sculptured, the anterior and posterior edges being raised, and a ridge running along the middle, above and below which are large oval depressions. The neural spine is longer and more slender and curved than that of an abdominal vertebra, and with a greater backward inclination. The zygapophyses are not so well developed. The hæmal arch and spine are almost exactly like the neural, and provided with anterior and posterior zygapophyses, which are, however, more imperfect than the superior.

¹ On removing the bone from the surface of this cartilage, it is seen to be attached by its broader end to the atlas. It passes from thence into the exoccipital bone, where it tapers to a point. If it be removed entire, and surrounded by a thin shell of bone, and a longitudinal section made, it is seen to be composed entirely of hyaline cartilage, the cartilage passing into the osseous tissue of the atlas behind, and into that of the exoccipital in front. It presents the appearance of an extosteal ossification extending from the atlas, and a similar extension from the exoccipital bone around a continuous rod of cartilage. This seems to imply a continuity of tissue between the parachordal cartilages and the first vertebra, such as occurs in the sturgeon (*accipenser*); but this is so much opposed to our present knowledge of bony fishes, that it could not be accepted, unless corroborated by embryological research.

The centrum, in both the neural and hæmal canals, is hollowed by a central depression, the hæmal being the deeper. Followed towards the tail, the vertebræ become gradually smaller, and in the last ten the spines are nearly straight, and are studded with little bony knobs, giving them a knotted appearance. In the antepenultimate vertebra the spines look like hypural bones. The penultimate has no spines, but articulates with two hypural bones below and two similarly-shaped bones above. The last vertebra is ankylosed to a terminal, triangular, bony plate. Followed forwards beyond the fifth caudal, the hæmal canal rapidly widens. On the fourth caudal a ridge appears on the side of the hæmapophysis. This becomes more pronounced on the third (Pl. VIII., fig. 22), and presents a secondary ridge in front. The hæmal canal is now very wide. In the second the ridges are stronger, and the anterior folded inwards, and their extremity projects like a transverse process. The first is a further exaggeration of this condition, and the vertebra appears to have a pair of parapophyses nearly identical in shape with those of the last abdominal, and in series with them, but connected near their lower ends, by a ribbon-like piece of bone, with a short hæmal spine. All the above-described ridges are in series with the parapophyses. Owing to the increase in size of the hæmal canal in the anterior caudal vertebræ, the spines become shorter, though their tips are nearly the same absolute distance from the centra.

The ribs, eighteen in number, are slender, curved bones, all of which articulate with the parapophyses, except the first; the middle are the longest, about two inches,¹ and the last is a very slender bone of about half an inch in length; the general inclination is downwards and slightly backwards; the posterior ribs also incline inwards, being in series with the lower part of the hæmal arches of the anterior caudals. The first rib differs both in shape and in manner of articulation from any of the others; it is stouter proportionally, and is from one-half to three-quarters of an inch in length;¹ the head is sunk in the above-described pit, in the body of the third vertebra; at a point about the middle of its dorsal surface it supports the first epipleural spine, which is about twice the length of the rib. The second rib is about the length of the

¹ In a haddock of thirty inches.

first, but more curved and far more slender; it articulates below, but in contact with, the second epipleural spine, with a groove on the postero-inferior surface of the parapophysis of the fourth vertebra (Pl. VIII., fig. 19). The third rib is similar, but more on the posterior border of the parapophysis; the fourth rib and epipleural spine are in contact for a shorter distance, and the parapophysis being longer, the two bones are removed farther from the body of the vertebra; the sixth rib and epipleural spine do not come in contact, the former being nearer the tip of the parapophysis; behind this they get farther apart, the ninth rib being about half an inch from the epipleural spine. All the ribs behind the fifth articulate with the posterior borders of the parapophyses (which are generally grooved for them)—the neck of the rib only articulating, and the head projecting into the lateral muscle.

The epipleural spines are curved bones resembling the ribs, but stronger; the anterior nine being large ($1\frac{3}{4}$ to 2 inches), but behind this they diminish rapidly, and disappear about the fourteenth. The first is supported entirely by the first rib, and the next four partly by rib and partly by parapophysis; behind this they articulate with small depressions about the middle of the posterior border of the parapophyses. Their direction is upwards, backwards, and outwards.

The Interspinous Bones and Fin-rays.—The general form of an interspinous bone (interhæmal or interneural) is a straight (sometimes curved) rod of bone, joined above at an obtuse angle with a thicker piece; the latter is hollowed at the end, and contains cartilage, which is prolonged into a rounded knob which supports the fin-rays; near the superior extremity of the bone in front is a saucer-like depression, formed by a prominent flange of bone; this supports the cartilaginous head of the interspinous bone in front and its articulation with the fin-rays. The first and second (most anterior) interneurals are very large, and expanded from before backwards, being the result of the fusion of several individuals.

The above description applies to the dorsal and anal fins; in the caudal fins there are no interspinous bones (unless the hypural bones be regarded as such),¹ but in its anterior part there are

¹ "Generally the hypurals are the interspinous bones alone, the arches being here obsolete" (Macalister, *op. cit.* page 74).

wedge-shaped interspinous pieces of condensed fibrous tissue, the ends of which are embraced by the fin-rays; behind this the fin-rays are in close juxtaposition to the hypural bones, a small quantity of the same fibrous tissue lying between their bases.

Each fin-ray is composed of two long, slender rods of bone, tapering to a very fine point; these are closely bound together, but diverge at their bases to embrace the cartilaginous continuation of the interspinous bone; at this part they are enlarged, and present several tubercles for the insertion of the elevator and depressor muscles of the fin, and for the attachment of ligaments.

The ligaments of the vertebral column are neither numerous nor very distinct.

Strips of fibro-cartilage bind the edges of the centra together, and membranous interspinous ligaments exist; in the region of the fins these expand into a dense network of fibrous and elastic tissue, which binds the interspinous bones to the tips of the neural (or hæmal) spines. The articulation between the interspinous bones and fin-rays is surrounded by a sort of capsular ligament, which is continuous with bundles of fibres which bind the distal ends of the interspinous bones together. The ligamentum subflavum is a strong band of elastic tissue, which occupies a space in the upper part of the neural canal, separated by a slight constriction from the lower part, or true neural canal. A ligament connects the anterior and posterior zyapophyses, and above this is a strengthened portion of the interspinous ligament; these are best seen in the anterior vertebræ.

The Shoulder-girdle and Pectoral Fin.—The shoulder-girdle consists of two bones, developed from cartilage—the scapula and coracoid—and several membrane bones—the clavicle (Pl. IX., fig. 24), supra-clavicle, and post-clavicle; to these may be added the post-temporal (Pl. IX., fig. 25), as belonging more properly to the shoulder than to the head.

The clavicle, being the largest bone, and articulating with four of the others, may be described first: it is a curved bone, the concavity being forwards, and the long axis running downwards and forwards; above it is compressed from side to side; below it forms an elongated cone, sharply pointed at the inferior extremity, and consisting of dense, compact tissue, solid to the very centre; the inferior extremity touches its fellow of the opposite side, being

bound to it by a few ligamentous fibres. Viewed from within, the conoidal part passes rather abruptly into the flattened portion, the posterior border of the latter being continued some distance down the former, as a prominent ridge; with the inner side of the end of this ridge the inferior angle of the coracoid articulates; another ridge, which projects internally, is seen along the anterior border; this runs into the superior angle of the bone above, while below it is lost where it joins the conoidal portion; near its lower end a thin shelf-like scale of bone diverges from it, and runs obliquely backwards and upwards to the posterior border; between these two (the ridge and the shelf) is a piece of cartilage, to which the anterior process of the coracoid is fixed, while the upper part of the shelf supports the scapula, which also articulates with the anterior border above it. The outer surface of the bone is marked by several grooves and ridges, for the attachment of muscles; below the pointed superior process is a deep, vertical groove, with which the supra-clavicle articulates.

The scapula is a slightly-curved scale of bone, deeply notched below; the upper and anterior borders articulate with the clavicle, and the inferior border on each side of the notch joins the coracoid, bounding the coraco-scapular fenestra; the posterior border supports a piece of cartilage, which is embraced by the anterior fin-ray, and below and behind this the first (or anterior), and part of the second, of the three radialia; these do not come in contact with it, being separated by a strip of cartilage.

The coracoid consists of a relatively thick, triangular portion above and behind (Pl. IX., fig. 24, *a*), a more elongated triangular portion above and in front, *b*, and a rod-like piece, which runs downwards from the junction of the other two, *c*. These are connected by intervening thin laminae.¹ According to Parker, these three pieces represent the præ-coracoid, meso-coracoid, and coracoid proper respectively.² The præ- and meso-coracoid articulate with the scapula; the meso-coracoid also with the clavicle; and the coracoid proper with the clavicle only. The præ-coracoid supports the remaining radialia and the metapterygial basale.

¹ "Periosteal spaces" (Parker, *On the Structure and Development of the Shoulder-girdle and Sternum*, page 53).

² *Loc. cit.*

The post-clavicle is a rod-like bone, pointed below, but expanded and flattened from side to side above. It is connected to the clavicle chiefly by muscle, the anterior superior angle, which is slightly overlapped by the posterior superior angle of the clavicle, being connected to the latter by a few ligamentous fibres. Its long axis is downwards and slightly backwards, forming an angle of about 45° with that of the clavicle.

The supra-clavicle (Pl. IX., fig. 25, *a*) is a thick, peg-like piece of bone, sharply pointed below and bevelled internally where it fits into the groove in the clavicle, truncated above and bevelled externally where it is overlapped by the post-temporal, an interosseous ligament binding them together.

The post-temporal (Pl. IX., fig. 25, *b*) presents a massive, ovate body below, which articulates with the supra-clavicle, and two limbs above—an internal and an external. The internal, which is much the larger, is curved and solid and rounded behind, but thin and excavated on its under surface in front; it ends in a sharp point, which fits into a groove on the upper surface of the parietal, and just behind this it articulates with the epiotic. The internal limb articulates with the inner surface of the opisthotic. Between the two limbs are four supra-temporals. These are thin, irregular, subcutaneous scales of bone, which are curved so as to form a gutter on their upper surface, which is occupied by mucous glands in the recent state. Three of these are arranged end to end along the inner limb, lying close to the epiotic and parietal. The other lies near the outer limb, and is applied against the pterotic. Behind these four is a much smaller scale, which occupies the posterior part of the notch on the upper surface of the bone, at the junction of the inner limb and the body. This may be a fifth supra-temporal, or the first "lateral line bone."¹

The mesopterygial basale is represented by the piece of cartilage which is embraced by the base of the anterior fin-ray. Below and behind this are the three radialis and the metapterygial basale. These are small hour-glass-shaped bones, with the exception of the first, or anterior radiale, which is somewhat semilunar in form. They are connected to a strip of cartilage which occupies the bifurcation of the proximal ends of the fin-rays.

¹ Cf. Parker on *Cottus bubalis* (*op. cit.*, page 43).

The pectoral fin consists of about nineteen rays, each of which is composed of two pieces firmly united together. These diverge at the base, and include within them a strip of cartilage, which is connected to the glenoid facet of the scapula and to the three radialis and the metapterygial basale. At their basal ends the rays are somewhat expanded, and present a double row of tubercles. Those of the inside (for the insertion of the double row of the tendons of the adductor muscles of the fin) are more largely developed, and lie farther apart than the outer ones. The latter are for the abductor muscles, and lie close together. The rays are marked with transverse constrictions, especially near their distal extremities. They continue as single rods for more than half their length, and then split longitudinally into halves, which show a further tendency to divide at their distal extremities. This cleavage is at right angles to the line of union of the two primary pieces of which each ray is composed. The first or anterior ray is very short, not more than half the length of the fin, but is the strongest of all. They increase in length up to the sixth, which is the longest. After this they diminish, the last two or three being very short and almost rudimentary.

Ligamentous fibres hold the limbs of the post-temporal in place, and a strong rounded ligament keeps the upper end of the clavicle from displacement backwards; it is attached to the postero-internal border of the supra-clavicle, and winds behind the superior process of the clavicle, piercing the lateral muscles, and notching the kidney, to be attached to the atlas in the manner above described.

The pelvic bone is similar in structure to the coracoid. It presents a thickish, triangular portion (Pl. IX., fig. 26, *a*), whose free border, slightly curved, looks outwards and slightly backwards. To this is attached a strip of cartilage, which supports the fin-rays. A rod-like portion, *b*, is attached to the inner angle of the above-mentioned piece, and stretches forwards and inwards, to be united with its fellow of the opposite side by cartilage, forming with it an angle of about 115° . This lies in the angle formed by the lower ends of the clavicles, and is connected to the latter by ligamentous and muscular fibres. A smaller flattened rod, *c*, passes backwards and inwards from the junction of the other two. Thin laminæ of bone connect these three pieces together.

The fin-rays resemble those of the pectoral fin, but are much shorter, and only six in number. The difference between the bases of the inner and outer portions is less marked than in the pectoral.

The otoliths are not described in this Paper, as they belong more properly to the anatomy of the ear than to the general osteology.

EXPLANATION OF THE FIGURES ON PLATES V. to IX.

Fig. 1. *The Skull from the side.*—1, supra-occipital; 2, pterotic; 3, ex-occipital; 4, opisthotic; 5, basi-occipital; 6, prootic; 7, parasphenoid; 8, vomer; 9, articular surface for palate bone; 10, ethmoid—the line points to the depression for the attachment of the maxillo-ethmoidal ligament; 11, prefrontal—the line points to the articular cavity for the lachrymal; 12, frontal; 13, sphenotic; 14, placed in the space for the interorbital septum, points by a line to the alisphenoid; *a*, foramen for glossopharyngeal nerve; *b*, articular cavity for head of hyomandibular.

Fig. 2. *The Skull from above.*—1 to 11, as in fig. 1; 10', apex of pyramidal portion of ethmoid; 15, epiotic; 16, parietal.

Fig. 3. *The Skull from behind.*—1, supra-occipital; 2, epiotic; 3, pterotic; 4, exoccipital—the line ends just above the foramen for the vagus nerve; 5, opisthotic; 6, basi-occipital; 7, foramen for first spinal nerve.

Fig. 4. *Superficial Dissection of the Left Side of the Head.*—1, points by five lines to the infra-orbital bones; 2, prefrontal; 3, hollow in nasal bone; 4, lachrymal; 5, premaxilla; 6, maxilla; 7, angle of mandible; 8, inter-operculum—beneath this are seen the branchiostegal rays; 9, condyle of quadrate; 10, pre-operculum; 11, sub-operculum; 12, operculum; 13, post-temporal; 14, ridge of pterotic; 15, epiotic; 16, suture between supra-occipital and frontal; *a*, piece of skin left surrounding the double nasal opening; *b*, *b'*, anterior, and *c*, posterior, maxillo-mandibular ligaments; *d*, ligament between inter-operculum and mandible; *e*, temporal muscle; *f*, abductor muscle inserted into hyomandibular; *g*, abductor of the operculum.

Fig. 5. *Left Palato-quadrate Arcade, with the Hyomandibular and Gill Cover, seen from the outer side.*—1, palate; 2, entopterygoid; 3, metapterygoid; 4, ectopterygoid; 5, quadrate; 6, interoperculum; 7, sub-operculum; 8, preoperculum; 9, symplectic; 10, triangular intercalary cartilage; 11, operculum; 12, hyomandibular; *a*, point of attachment

of palato-premaxillary ligament; *b*, of entopterygoid-prefrontal ligament; *c*, fenestra, through which passes posterior branch of facial nerve; *d*, for anterior branch of facial.

Fig. 6. *Right Exoccipital from behind (enlarged)*.—*a*, dotted line adjacent to the edge, which articulates with atlas; *b*, with supraoccipital; *c*, with epiotic; *d*, with opisthotic; *e*, points by two lines to the extremities of the edge, which articulates with basioccipital; *f*, with exoccipital of opposite side (the edges *e* and *f* are concealed by *a* and *b* in the figure); 1, foramen for vagus nerve; 2, for first spinal nerve; 3, articular process, which joins the lower articular process of the atlas (see fig. 20, 2), and contains a core of cartilage, which is continued into the atlas.

Fig. 7. *Left Hyomandibular from the outer side*.—1, head, which articulates with the cranium; 2, foramen for anterior branch of facial; 3, part of anterior process, which joins the triangular intercalary cartilage; 4, condyle for the operculum; 5, middle process.

Fig. 8. *Pre-ethmoid Cartilage from the left side*.—1, line of attachment of ligament from premaxilla; 2, groove for palato-premaxillary ligaments; 3, attachment of ligament from maxilla.

Fig. 9. *Right Premaxilla: a, Inner; b, Outer View*.—1, point of attachment of premaxillo-palatine ligament; 2, articular surface for pre-ethmoid cartilage; 3, dotted line, showing attachment of ligament to pre-ethmoid; 4, for opposite premaxilla; 5, for maxilla; 6, attachment of ligament to maxilla; 7, inferior process.

Fig. 10. *Right maxilla: a, From the inner side*.—1, attachment of ligament to premaxilla; 2, maxillo-pre-ethmoid ligament; 3, tubercle for the insertion of a muscle (Cuvier's "analogue of the masseter"); 4, articulation with ethmoid. *b. From the outer side*—5, maxillo-ethmoid ligament; 6, for premaxilla; 7, for palate; 8, for posterior; and 9, for anterior, maxillo-mandibular ligaments.

Fig. 11. *Left Interoperculum from the inner side*.—1, hollow, which supports the articulation of epi- with stylo-hyal.

Fig. 12. *Left Operculum from the inner side*.—1, groove for insertion of adductor operculi; 2, cavity articulating with hyomandibular.

Fig. 13. *Deep Dissection of the Left Side of the Head*.—1, nasal branch of trigeminal nerve crossing roof of orbit; 2, tip of ethmoid; between 2 and 6 the maxillo-ethmoid ligaments; 3, olfactory bulb; 4, pre-ethmoid cartilage; 5, apex of premaxilla; 6, maxilla—a little to the right of the line is seen the articulation of the palate; 7, posterior mandibular ligament; between 5 and 8 palato-premaxillary ligament; 8, attachment of the same to palate bone—just behind this the articu-

lation of palate and prefrontal; 9, anterior maxillo-mandibular ligament at its junction with a ligament from the premaxilla; 10, a small muscle (cut and thrown downwards), which arises by an aponeurosis from the preoperculum, and is inserted into the posterior maxillo-mandibular ligament ("muscle carré" of Cuvier); 11, articular surface for the lachrymal bone; 12, attachment of posterior maxillo-mandibular ligament to mandible; 13, condyle of quadrate; 14, cut end of the superficial part of the temporal muscle; 15, preoperculum; 16, inferior maxillary division of trigeminal nerve; 17, superior maxillary division of the same; 18, deeper part of the temporal muscle—this passes under the tendinous origin of a muscle which is inserted into a tubercle on the maxilla (see fig. 10, *a* ³), and is considered by Cuvier to be the analogue of the masseter;¹ it lies between the lines 16 and 17 in the figure; 19, condyle of hyomandibular for the operculum; 20, articular head of hyomandibular; 21, adductor muscle of hyomandibular; 22, ridge of pterotic.

Fig. 14. *Right Nasal Bone from above.*—*a*, posterior extremity; *b*, outer edge.

Fig. 15. *Left Half of Hyoid Arch from the outer side.*—1, stylohyal; 2, epihyal; 3, ceratohyal; 4, superior hypohyal; 5, inferior hypohyal; *a*, foramen, which transmits the artery to the pseudobranchia.

Fig. 16. *Bones of the Gill Arches of the Left Side, with the Basibranchiostegal and the Ossification in the Copulæ.*—*a*, *b*, and *c*, the three pieces of the epipharyngeal bone, from above; 1, for articulation with epibranchial of first branchial arch; 2, for that of second arch; 3, for those of third and fourth arches; *d*, basibranchiostegal, from the right side—the letter is placed near the posterior border; *e*, ossification in the copulæ, from above; *f*, *f'*, *f*, hypobranchials, from above; *g*, *g'*, *g''*, *g'''*, ceratobranchials, from behind; *h*, hypopharyngeal bone, from behind; *k*, *k'*, *k''*, *k'''*, epibranchials, from behind; 4, 4', processes of epibranchials of third and fourth arches, which articulate with one another.

Fig. 17. *Ninth Abdominal Vertebra, from before.*—1, neural spine; 2, neural canal—the line points to the constriction which separates the canal for the ligamentum subflavum from the true neural canal below; 3, centrum; 4, groove for aorta—*e* and *r* point to the articular surfaces on the posterior surface of the parapophysis for the epipleural spines and ribs respectively.

¹ *Op cit.*, vol. iv. i. p. 171.

Fig. 18. *Fifth Abdominal Vertebra from before*.—*p*, Parapophysis ; , epipleural spine ; *r*, rib.

Fig. 19. *Fourth Abdominal Vertebra from before*.—Letters as in fig. 18.

Fig. 20. *Atlas from the right side*.—1, Anterior zygapophysis ; 2, lower articular process (for exoccipital) ; 3, posterior zygapophysis ; 4, pit for attachment of ligament to supra-clavicle.

Fig. 21. *Third Abdominal Vertebra from before*.—*r*, rib ; *e*, epipleural spine.

Fig. 22. *The four last Abdominal and first three Caudal Vertebrae from below and slightly from the right side*.—1, Parapophysis of abdominal vertebra ; 2, process of hæmal arch of first caudal ; 4, ribbon-like piece of bone connecting the latter to 3, the hæmal spine.

Fig. 23. *An Interspinous Bone (slightly enlarged)*—*a*, from the side ; *b*, from before.—1, Hollow portion, which is continuous with the piece of cartilage with which the fin-rays articulate ; 2, saucer-like portion, which supports the articulation of the interspinous bone and fin-ray next in front.

Fig. 24, A. *Shoulder Girdle and Fin of the left side from within*.—*a*, *b*, *c*, coracoid—*a*, præ-coracoid ; *b*, meso-coracoid ; *c*, coracoid proper ; 1, scapula ; 2, the anterior of the three radialis ; 3, cartilage between coracoid, scapula, and clavicle ; 4, clavicle—the line points to the conoidal portion ; 5, the metapterygial basale, B. *Upper portion of the same (slightly reduced)*, with the scapula and coracoid removed, showing, 6, the shelf-like process of bone which supports the scapula, and, 7, the post-clavicle in its natural position.

Fig. 25. *Left Supra-clavicle, a, and Post-temporal, b, from above*.—1, Outer or lower, and 2, inner or upper, limb of the post-temporal ; 3, articular surface of supra-clavicle for post-temporal.

Fig. 26. *Left Pelvic Bone from above*.—*a*, Portion of the bone which supports articular cartilage for the fin-rays—the cartilage is dotted ; *b*, rod-like portion—the line points to the extremity where it joins its fellow of the opposite side.

XXII.—NOTE ON THE BOTANICAL TOPOGRAPHICAL DIVISIONS OF IRELAND. BY W. R. McNAB, M.D., F.L.S., Professor of Botany, Royal College of Science, Ireland; Scientific Superintendent of the Royal Botanic Garden, Dublin.

[Read, January 21, 1884.]

BEING at present engaged in the re-arrangement of the collection of British and Irish plants in the Herbarium at the Royal Botanic Garden, Glasnevin, it was necessary for me to consider what steps ought to be taken towards the formation of a collection illustrating the "Cybele Hibernica." Special considerations rendered it advisable to keep all the British and Irish plants together for the present, the space at my disposal not permitting of the formation of a special "Cybele Hibernica" collection. All the advantages I wished for could, I found, be got by simply introducing a printed sheet into the Herbarium with each species, headed "Cybele Hibernica," and bearing the number, name, and the recorded distribution of the plant in Ireland. Taking Watson's "Topographical Botany" as a good model, it became necessary to revise the whole Botanical Topography of Ireland, and to bring the "Districts" of Moore and More's "Cybele Hibernica" into greater conformity with the divisions adopted for England, Wales, and Scotland. At the same time it was of the utmost importance to make as little alteration as possible in Babington's Districts as adopted by the Authors of the "Cybele Hibernica," as all alterations would tend to produce confusion. Watson adopts a division into Provinces, Vice-provinces, and Vice-counties, for the "Cybele Britannica," and Babington divided Ireland into Districts. I propose simply to adopt Babington's "Districts," but to call these "Provinces," distinguished not by a number only, but by a roman numeral and a name. In this way the name will obviate the necessity of constantly referring to a map when any District or Province is mentioned by number. Vice-provinces, as adopted by Watson, are unnecessary in the Botanical Topography of Ireland. The next division, that of Vice-counties, or of Counties and parts of Counties, must however be

adopted; and following the “Cybele Hibernica” as closely as possible, we must at least adopt thirty-six Vice-counties. In the majority of cases these Vice-counties are the ordinary comital divisions, it being necessary in comparatively few cases to divide the county into two parts, although it is possible that in a few cases further subdivision might be made. In naming the Provinces the names of the four great Provinces of Ireland have been used; and it is only in the cases of Provinces VI. and VII. that this has been departed from, and the terms West and East Shannon have been adopted, although the former does not all lie West of the Shannon.

The following is a tabular view of the proposed Provinces and Vice-counties:—

PROVINCES AND VICE-COUNTIES.

PROVINCES.	VICE-COUNTIES.
I.—West Munster, 	1 Kerry. 2 South Cork.
II.—East Munster, 	3 North Cork. 4 Waterford. 5 South Tipperary.
III.—West Leinster, 	6 Kilkenny. 7 Carlow, 8 Queen’s County.
IV.—East Leinster, 	9 Wexford. 10 Wicklow.
V.—North Leinster, 	11 Kildare, 12 Dublin. 13 Meath. 14 Louth.
VI.—West Shannon, 	15 Limerick. 16 Clare. 17 East Galway.
VII.—East Shannon, 	18 North Tipperary. 19 King’s County. 20 Westmeath. 21 Longford.

PROVINCES.	VICE-COUNTIES.
VIII.—West Connaught,	22 West Galway.
	23 West Mayo.
IX.—East Connaught,	24 East Mayo.
	25 Sligo.
	26 Leitrim.
	27 Roscommon.
X.—South Ulster,	28 Fermanagh.
	29 Cavan.
	30 Monaghan.
	31 Tyrone.
	32 Armagh.
XI.—West Ulster,	33 Donegal and city of Londonderry.
XII.—East Ulster,	34 Down.
	35 Antrim.
	36 Derry.

By adopting these divisions it will be easy to record, on a single sheet, all the Vice-counties in which any given plant has been observed, by simply marking off the number and name, while space will be left after each name for an entry of the authority or exact locality if necessary. Further, I believe, it will be a great advantage to students to have the "Districts" named instead of merely numbered; and also it will be much more easy to compare the distribution of species in Great Britain and Ireland now than it was formerly when totally different divisions were adopted.

XXIII.—DESCRIPTION OF AN APPARATUS FOR DEMONSTRATING SYSTEMS OF CLASSIFICATIONS, ETC.
 BY ALFRED C. HADDON, M. A., Professor of Zoology,
 Royal College of Science, Ireland.

[Read, January 21, 1884.]

A METHOD of classification which would indicate the affinities of organisms to one another has for a long time been the aim of biologists, and they have more or less succeeded, by arranging the names of the forms whose affinities they desired to illustrate in a given manner, and connecting them by means of lines.

The older zoologists, for instance, were content with arranging the names in a continuous sequence, thus forming a linear series or *a classification in one dimension of space*.

It was soon found that such an arrangement by no means indicated the real affinities, nay more, tended to retard a true conception of the animal kingdom as a whole; so recourse was had to arranging the names in a dendritic manner on a flat surface, the length of the lines, their position, and their various ramifications illustrating the supposed relative position of the animals themselves. This constituted *a classification in two dimensions of space*.

Some zoologists, however, have felt that even this method was insufficient to express their views; but, so far as I am aware, this want has not yet been supplied; and it has occurred to me that what was really required was a system which would more accurately render in space that well-known figure of speech—the Genealogical Tree—and that the facts of the case could be more closely represented by a solid method of classification—in other words, by *a classification in three dimensions of space*.

Unfortunately such a system requires a special apparatus, and is not adapted for ordinary representation on plane surfaces; but the apparatus I propose is very simple, merely consisting of a series of glass plates placed vertically over one another, leaving a small space between each, and a number of small movable blocks.

The exact method for supporting the glass plates is of no con-

sequence, and may be varied to any extent. The apparatus which I employ consists of an oblong mahogany board, let into the corners of which are four brass sockets; into these are inserted four brass standards which are pierced with holes at regular intervals, in such a manner that the holes in each end-standard are *vis à vis* with those of its fellow, and are at the same time parallel with those at the opposite end. Through these holes brass wires are inserted, and it is upon these that the glass plates rest. This apparatus has the advantage of being readily taken to pieces, and in being quite portable.

The names should be printed on paper, then cut out and pasted on two faces of oblong blocks of wood, in such a manner that they can be read in a front view or by looking down vertically upon the apparatus. A makeshift may be constructed by bending a small oblong piece of cardboard roofwise, and writing the name on one face of the anticlinal.

The several blocks may be linked together in the same plane by pins inserted in the sides, or to those of the plane above by pins placed either vertically or obliquely, and reaching to the upper glass plate. Any complicated system of linkage is thus possible.

There are two obvious uses to which this apparatus can be put in Zoology, viz., to represent a classification of recent forms and for phylogeny.

In a classification of recent forms, each plate might represent a stage of differentiation, and the arrangement of the forms on that superficies would indicate their inter-relationships. The lower planes would naturally be chosen for the less differentiated types. An area on each plane could always be made by a coloured line to represent some special modification. Degraded animals might be tinted, and a black pin slanting from the higher to the degenerate form would graphically show that it was not an ascending type. Missing links between more or less widely-separated living animals could be appropriately supplied by names within brackets.

For phylogeny the arrangement would be somewhat similar, except that each plate would represent some geological horizon, the name of which would be on a block placed in one corner. Every name in each geological epoch should be tinted in some distinctive colour, so as to distinguish at a glance its precise horizon (it would be well to adopt the Survey colouration).

In the case before us only a general classification can be attempted, and degraded forms could only be represented by a special colour.

This system presents us with certain advantages over the ordinary graphic methods: for instance—on each glass plate is a collection of the representatives of any group which occur in a particular stratum. These forms are the chronological data of the ordinary stratiographical geologist; and it matters not to him how these may be arranged upon the plane.

The philosophical palæontologist arranges the names on each plane so as to indicate the relations of each animal to those preceding and succeeding it in time, as well as to its synchronous neighbours, and thus he gets a graphic view of the march of life; by looking from above down the vista of time he sees widely-separated recent animals gradually converging till they all unite in some form which, if at present unknown, must once have existed; or, more accurately, diverging from such a common ancestor. It will also be made apparent that in every age there were forms which varied from the parent stem, which lived for a longer or a shorter period and then became extinct.

Very valuable museum demonstrations could be made by fitting up a comparatively large apparatus, to the glass plates of which were cemented real fossils with their names. Ammonites and Brachiopods, for instance, are well fitted for this purpose. Affinities and variations would in this case be illustrated by the actual specimens, and so be vividly impressed upon the mind.

By drawing or etching on each glass plate a similar outline map of the world on Mercator's projection, and by allocating one of the smaller subdivisions of the Cainozoic period to each, the migrations of animals could be indicated in terms of time and space. This would naturally necessitate a separate series of plates.

It is needless to dwell further upon the possibilities of such an apparatus; for I feel confident that it will prove of use in many other ways, and in other branches of knowledge than in those indicated above.

I may add that I have employed this system for nearly two years, and have found it to answer admirably.

XXIV.—REMARKS ON THE UNUSUAL SUNRISES AND SUNSETS WHICH CHARACTERISED THE CLOSE OF THE YEAR 1883. BY REV. SAMUEL HAUGHTON, S.F.T.C.D., M.D., F.R.S.

[Read, January 21, 1884.]

THE older writers on Astronomy, such as Brinkley and Maddy, state that, on the average, twilight lasts until the sun is 18° below the horizon. From this it has been computed that the height of the twilight-producing atmosphere is

40 miles on hypothesis of one reflexion,

12	„	„	„	„	two	„
5	„	„	„	„	three	„
3	„	„	„	„	four	„

Herschel and Newcomb make no statement whatever as to the duration of twilight; Chambers (in his compilation) says that the average depression of the sun is 18° , which is reduced to 16° or 17° in the tropics, but in England a depression ranging from 17° to 21° is required to put an end to the twilight phenomena.

Dr. Ball informs me that Professor Schmidt, of Athens, gives (for that place) $15^\circ 51'$; and also that Liais (Paris) fixes the first twilight arc to set at $10^\circ 41'$, and the second arc at $18^\circ 18'$.

In the following conclusions, drawn from the phenomenal twilights of the autumn of 1883, I calculate the zenith distance of the sun, at the close of the phenomena, by the well-known formula

$$\cos z = a + \beta \cos h,$$

where

z = sun's zenith distance.

h = sun's hour angle.

$a = \sin \lambda \sin \delta$.

$\beta = \cos \lambda \cos \delta$.

λ = latitude of place of observation.

δ = declination of sun.

Observation (1).—Mr. Bishop, observing at Honolulu, found the phenomenal sunsets to commence on the 5th September, 1883, and to last up to 7^h 25^m P.M.

Here

$$\lambda = 22^{\circ}.$$

$$\delta = 6^{\circ} 16'.$$

This gives the sun's place, at the close of the phenomena, $18^{\circ} 22'$ below the horizon.

This indicates twilight phenomena intensified by some unusual cause, but does not denote an extension of twilight reflexion into regions of the air higher than the time-honoured traditional 40 miles.

The epoch of the main eruption of Krakatoa has been fixed by General Strachey at August, 27^d 9^h 32^m, A.M.

If the explosion of Krakatoa, on the 27th August, was the cause of the brilliant sunset at Honolulu, on the 5th September, the result is nothing short of miraculous !

The Editor of *Nature* writes, on the 20th December, with an enthusiastic glow worthy of the twilights :—“The extraordinary fact now comes out, that before even the lower currents had time to carry the volcanic products to a region so near the eruption as India, an upper current had taken them in a straight line *viâ* the Seychelles, Cape Coast Castle, Trinidad, and Panama, to Honolulu; in fact very nearly back again to the Straits of Sunda !” [The note of admiration is not mine.]

It is worth our while to calculate the rate at which this wonderful journey of volcanic dust was performed. The actual distance is 255° of a great circle, and the time of journey 9 days, from which I calculate the speed of the train to have been 82 miles per hour ! This is absolutely incredible, and becomes still more so when we know that the phenomena observed at Honolulu on the 5th September were unusual twilight phenomena, but had no connexion whatever with reflexion from the upper regions of the air. In point of fact, my calculation of the sun's position disproves the presence of dust, or any reflecting substances in the upper air.

Observation (2).—Dr. Ball (Dunsink).—“Sunday evening, 30th December, was exceptionally fine, and the sunset was so well seen

that the moon (though only 27 hours old) was well seen by Cathcart and myself from the roof of the Observatory.

“We estimated that the twilight lasted certainly for two hours after sunset, and that for ten minutes longer there was still enough light in the western sky to distinguish it from other parts of the horizon.

“At 2 hours after sunset the sun was $15^{\circ} 56'$ below the horizon, and at $2^h 10^m$ it was $16^{\circ} 51'$ below the horizon.”

Observation (3).—On the 25th December Mr. William Graves, observing at Kingstown, found it was “black night” at 5.30 P.M. This gives $14^{\circ} 15'$ below the horizon for the sun’s position.

Observation (4).—Mr. Frederick Haughton, writing from Carlow, says, of the evening of 30th December :—“I have of course seen a good deal of the after-glow: some evenings the appearance is like the glare of lime-light at a theatre; the effect on grass or gardens very strange; with back to west every blade of grass is like fire, a bit of straw like a red hot needle; but facing the light it is all lurid light and shade. Last night sun set by almanac at 3.47; here the sun disappears 20 to 25 minutes before, owing to hills; at 4.30 the glow was splendid; at 5.10 I could see the second-hand of watch. 1 hour 23 minutes after sunset, or nearly $1\frac{3}{4}$ hour after sun had vanished from us, a planet¹ from 4.30 to 5.30 was in the glow; and from 5 to 5.30 was bright emerald green!”

Supposing the termination of the phenomena to be at 5.40 P.M., this would correspond to a position of the sun $15^{\circ} 15'$ below the horizon.

¹ Venus.

XXV.—A SIMPLE METHOD OF OBSERVING FAINT LINES
WITH DIFFRACTION SPECTROSCOPES. BY W. N.
HARTLEY, F.R.S.E., &c., Professor of Chemistry, Royal
College of Science, Ireland.

[Read, January 21, 1884.]

IN observing spark spectra with diffraction gratings there is generally much difficulty attending the measurement of faint lines; moreover, the eye becomes fatigued when regarding for any long period rays of one colour only, and in endeavouring to catch sight of the cross wires on a darkened field. During a spectroscopic examination of the rare earths contained in the mineral *rhabdophane* ("Chemical Society's Journal"—Transactions, vol. xli., p. 210), a somewhat painful experience led me to devise a means of not only giving relief to the eye, but of greatly facilitating the measurement of the lines. I work in a darkened room, the goniometer of the spectroscope being illumined by a shaded lamp which stands to right of the telescope. The grating is movable, while the collimator and telescope are fixed in such a position as to include as small an angle between them as possible. The telescope being to the right of the collimator, a small gas jet is placed upon the left, the rays from which proceed to the grating and are reflected into the field of the telescope. By the adjustment of this light the field may be illumined in any colour of the spectrum, and by selecting that tint which is complementary to the colour of the lines to be measured, they are seen to stand out apparently in relief on a bright ground. The intensity of the illumination of the field must, of course, be regulated according to the strength of the lines to be measured. Many of the lines in the spectrum of yttrium obtained from *rhabdophane* could not have been measured had it not been for this method of working.

XXVI—NOTES ON THE CLASSIFICATION OF THE BOULDER-CLAYS AND THEIR ASSOCIATED GRAVELS. BY G. H. KINAHAN, M. R. I. A.

[Read, January 21, 1884.]

THE phenomena to be observed in connexion with the boulder-clays and their associated gravels, &c., especially in Ireland, are far from having been satisfactorily explained; it may therefore be allowable to make some remarks on them.

It would appear as though the present confusion is in a great measure due to observers rushing to conclusions without sufficient and careful examination or thought, and also forgetting to compare the deposits that they would explain with those that are being laid down at the present time.

There are three classes of more or less similar drifts, which are commonly called boulder-clay:—

- 1st. The TILL, or the Lower Boulder-clay.
- 2nd. MORaine DRIFT, or the Upper Boulder-clay.
- 3rd. GLACIALOID DRIFT.

Nos. 1 and 2 are true glacial drifts; while No. 3 was originally glacial drift, but has subsequently been re-arranged, either by water or atmospheric agencies. Associated with all, but especially the last, there are gravels, sands, with brick and “book” clays, or, under certain circumstances, marls. These occur sometimes above, sometimes below, but more often in different intermediate positions, while in general the relative positions of these different drifts are supposed to indicate their relative ages. This, however, appears to me to be “not proven,” as the facts observed by Clarence King on the Western Pacific slopes, and by Hayes and others in Arctic and Alpine regions, combined with what can be studied as taking place at the present day in Great Britain and Ireland, would suggest otherwise.

Prior, however, to going further into these subjects, we may give a *résumé* of the principal sections in Ireland that are said to afford conclusive evidence of there having been upper and lower glacial drifts, with “middle gravels” of an intermediate age between them.

There are, indeed, in the neighbourhood of different groups of hills two distinct varieties of boulder-clay, viz. *till* below, and *moraine drift* above; but although in general there is a line of boundary between, yet they are rarely separated by aqueous deposits; while if they are so, the latter usually consist of from a few inches to a few feet in thickness of fine sand or finely laminated clay (*book clay*); and in such places there is nearly always a "lining" or rude stratification in the overlying moraine drift, as if it had been finally arranged in water—or as if it had slipped down from a higher level in the state of mud, or of mud and ice-slush mixed together. In many places the latter is suggested, as on the low, flattish ground this lining may be very conspicuous; while as we ascend to the higher sloping ground all traces of this stratification gradually disappear.¹ In no place, however, have I seen regular continuous sands and gravels between these upper and lower glacial drifts; although in places, more especially along some of the sea cliffs, there are miles of sections exposed.

The section which appears to be most relied on as a proof of the existence of these "middle gravels" in Ireland is that at the Kilkenny marble quarry. Here, however, the upper member is not a *true* glacial drift, but a very typical estuarine accumulation—one common in the deep-seated Irish river-valleys, having in it many striated fragments, but all more or less water-worn, while it is similar to drift now accumulating in different long, narrow estuaries. In some of these recent estuarine accumulations I have found over 50 per cent. of these striated fragments.

In various places along the coast from Killiney to Bray, both in the railway cuttings and the cliff sections, it is quite evident that the gravels, brick-clays, &c., were deposited at the base of a boulder-clay cliff, which at times slipped down and covered them, thereby causing glacialoid drift to dovetail and merge into gravels, sands, and clays.

More or less similar phenomena can be seen in the coast cliffs of Wicklow, Wexford, Waterford, Louth, Down, Antrim, &c., and inland in numerous places. Inland, especially in the Co. Tyrone, the gravel is often found surrounding glacial drift-hills,

¹ As has been pointed out elsewhere, on the N. W., or Carlow, slopes of Mount Leinster, there is a lined glacialoid moraine drift that now extends out on to a recent peat bog ("Geology of Ireland," p. 236).

but in such cases never extending through them, as is proved by the railway cuttings. A very instructive case occurs at Redhill, to the west of Boyle, Co. Roscommon, and is described in the Geological Survey Memoirs by Mr. Cruise.

In some places, as in the vicinity of Pomeroy, Co. Tyrone, an angular, shingly drift has been called "upper boulder-clay," although there is not a particle of evidence to suggest a glacial origin; while elsewhere high level gravels, as on Slieve Gallion Carn, Co. Londonderry, are said to be of the same age as the gravels of the low neighbouring plains, and as they are under glacial or glacialoid drifts, are said to prove that the latter are those so-called "middle gravels"; although it must be evident to anyone who examines them thoroughly, and carefully considers the subject, that the higher gravels must be quite distinct, and are probably older than the lower ones.

The result of many years' minute examination and consideration of the drift accumulations in various places in the United Kingdom, combined with a study of the published descriptions of drift sections by numerous observers there and elsewhere, would lead me to suggest—

First—That some of the gravels and other stratified drifts under glacial drifts may be younger than the overlying deposits.

Second—That many of the sands and gravels in the till and moraine drifts are probably younger than the materials now lying over them; and

Third—That gravels, sands, and other stratified drifts contemporaneous with the allied glacialoid drift, must in general be younger than the associated glacial drifts; the exceptions being few and rare.

As to the first: in certain places the till or moraine drifts may have accumulated over deposits of gravel or such like; but in other places it seems highly probable that the gravels now found under them were due to the water formed in the ice before and during its final melting, producing streams under the glacial drift, thereby washing portions of it into gravels and sands. This is specially suggested by finding boulders in places in these accumulations, while the stratification is distorted as if by currents curling round the boulders, or by the roof falling in; also, many of those who

have studied "live ice" mention the streams that flow from beneath the glaciers and ice-sheets.

As to the second: Clarence King and others who have studied the dying-out of ice-sheets have found that the ice melts from above and below, leaving to the last patches and cakes on different horizons. The waters due to such cakes, when they finally melt away, must wash portions of the glacial drift into sands and gravels formed and arranged subsequently to the overlying drift.¹

Similarly in the till and moraine drifts we find on different horizons, cakes and patches of gravel and sand, often very irregularly stratified, as if there was a curling current, or that the roof and sides of the cavities fell in, as the cakes of ice gradually melted away. In various Papers on the English and Scotch drift such cakes and patches of sand and gravel on different horizons are appealed to as proofs of the existence of "middle gravels" of intermediate age; but, if my theory is correct, they are younger than the overlying deposits. Also, if large debacles of glacial mud slide down to form the upper drift, the water from the snow-slush, or even from the mud alone, should form sands, "book clays," and the like, between this soft matter and the harder floor beneath.²

As to the third: gravels and other stratified drifts, when associated with glacialoid drifts, must be younger than the original glacial drift with which they are connected; as the glacialoid drifts were formed from the *debris* of the last, while they are interstratified with the first. If the original drift cliff was perpendicular, or nearly so, the gravels would accumulate against it, whilst subsequently detritus, composed by weathering from the upper portion of the cliff, would cover them up; but if there were periodical falls or slips of the cliff, the gravels and glacialoid drifts must in some places be more or less interstratified, whilst elsewhere they would blend or graduate into one another, as can be seen in numerous places along the already-mentioned Irish coast cliffs.

¹ Some of the cakes may be isolated and surrounded by the clay, thus forming "lough holes" like those cut when making the railway under the Phoenix Park, Dublin. These lough holes seem to have been filled for the most part with water, there being only a little sand.

² If the floor is a rock surface we find in uneven places small patches of these stratified drifts, which apparently were formed subsequently to that over them, as they fit the roof of the cavity similar to matter found filling a rock cave.

XXVII.—NOTE ON THE COAL DEPOSITS OF THE NORTH-WEST TERRITORIES OF CANADA. BY GERRARD A. KINAHAN.

[Read, February 18, 1884.]

As some doubts are still often expressed in this country of there being sufficient fuel in the North-West to supply even the local requirements of Manitoba, Assiniboia, and Alberta, a short note on the lignite deposits of this region may be of some interest to the Members of this Society.

The formations in which these beds occur are considered by the Officers of the Geological Survey of Canada to be of later Cretaceous or early Eocene age, and in some cases there is evidence of the lignites occurring on two distinct geological horizons, very possibly representing a period intervening between the Mesozoic and Cainozoic of Europe. The lignite-bearing series probably underlies a large portion of the prairie lands of the North-West, being concealed by a thick covering of drift gravel and alluvium; its outcropping at the surface is generally the result of gentle undulations of the strata and subsequent denudation.

In the eastern portion of the area the fuel is more truly lignitic; but westward, especially in the folded and compressed strata composing the foot-hills of the Rocky Mountains, it more nearly approaches in lithological characters true coal. West of the Foot-Hills this formation is cut off by an immense fault with a large downthrow to the east, beyond which break Palæozoic limestones and quartzites form the precipitous and craggy range of the Rocky Mountains. That the lignite-bearing series formerly had a wider distribution and covered much of these Palæozoic rocks is evident from the fact that, far in in the mountains, a small patch of them occurs, resting on the older rocks, which have here been let down by a series of faults, thus preserving the overlying series from being denuded away. Here the lignite has been converted into a semi-anthracitic coal of very excellent quality, free from pyrites and slate, and quite undeserving of the name of lignite in any sense but that of being of post-carboniferous age. It appears on the Devil's Creek, or north fork of the Bow River, at Cascade Park,

twenty-five miles from Padmore, and about eighty miles west of Calgary, close to the line of the Canadian Pacific Railway. But although this valuable deposit has been known for many years to some of the early prospectors of this section of the mountains, it was not till last summer that the location was secured, and in the Fall active operations for extracting the fuel commenced.

Along the belt of the Foot Hills, where the strata are more folded and indurated than on the plains to the east, the coal seams crop out more highly inclined, and the beds are probably often repeated. About twenty-eight miles from Calgary, and ten miles east of Morley, an important coal outcrop occurs in these beds; it is that of Coal Creek, in the Wildcat Hills, on the Cochran Rancho, where the seam appears to be about five feet thick, dipping east, at an angle of about 30° , under a series of cream-coloured sandstones. Most of the other outcrops in this belt are too far removed from the line of railroad or other convenient means of transport to be of much economic value at present, but eventually many will probably prove important. Dr. G. M. Dawson has recorded several outcrops in this district, as that on the Big Cottonwood River, north fork of Highwood River, and the north fork of the Old Man's River, near the Crow's Nest Pass, and on the middle fork in the vicinity of the Kootenai Pass; also a thick seam, about ten feet wide, on Mill Creek; these two last locations are about forty miles west of Fort M'Leod. On a specimen from an outcrop on the Indian Supply Farm, a little further south-east, Mr. Hoffman publishes a report and an analysis¹ which may be quoted:—

“Colour, pure black; structure, lamellar; lustre, shining resinous, with occasional dull patches; powder, black, the same communicating a deep brownish-red colour to a boiling solution of caustic potash.

“ANALYSIS BY SLOW AND FAST COKING.

	Slow Coking.	Fast Coking.
Hygroscopic water,	6.26	6.26
Volatile combustible matter,	29.31	31.96
Fixed carbon,	55.70	53.05
Ash,	8.73	8.73
	100.00	100.00

¹ Chemical Contributions to the Geology of Canada (1880), by Christian Hoffmann, F. Inst. Chem. (page 12.)

“Both slow and fast coking gave a *pulverulent* coke. The ash had a pale reddish-brown colour, and agglutinated slightly at a bright red heat.”

These localities all lie to the south of the Canadian Pacific Railway, towards the United States boundary; but to the north many other outcroppings also occur in the Edmonton district, one seam, twenty feet thick, appearing on the Saskatchewan, above Edmonton, and another, eight feet thick, on the Pembina River.

In the vicinity of the railway, on the Bow River, there are two important outcrops, near the Blackfoot crossing, and on Crowfoot Creek; these locations are about sixty miles east of Calgary and one hundred and ten west of Medicine Hat, where the seams vary from three to nine feet thick, and dip gently towards the west; other outcrops occur on the Red Deer River, which lies to the north. The following analyses have been published by Mr. Hoffmann:—

	BLACKFOOT CROSSING.		CROWFOOT CREEK.	
	Slow Coking.	Fast Coking.	Slow Coking.	Fast Coking.
Hygroscopic water,	10.72	10.72	11.25	11.25
Volatile combustible matter,	29.26	32.63	31.98	35.59
Fixed carbon,	46.09	42.72	50.85	47.24
Ash,	13.93	13.93	5.92	5.92
	100.00	100.00	100.00	100.00
Ratio of volatile combustible matter to fixed carbon,	1 : 1.57	1 : 1.31	1 : 1.59	1 : 1.33

These samples gave a pulverulent coke, and agglutinated slightly at a bright-red heat. The coal is of a black colour with a brownish tinge, and contains thin films of selenite.¹

¹ From these analyses, by fast and slow coking, of the proximate composition of the coal we may roughly appreciate its value as a fuel and gas-producing material, though the fixed carbon and volatile matter vary *inter se* according to the method of coking: of course the ash and hygroscopic water are constant under both conditions. “Lignites” always contain a large percentage of the latter, so that its accurate estimation is of the utmost importance. In these samples the hygroscopic water appears to be exceptionally low: for lignites generally the average percentage varies from 15 to 25 per cent., and in exceptional cases it runs as high as 50 per cent. However, the action of caustic potash in the present instance indicates the lignitic character of the fuel. Another important point to be determined in estimating the commercial value of lignite is the question of weathering. Most of the lignites of the north-west appear to bear the weather and transport well, the arid climate and the comparative freedom of the coal from unstable pyrites being specially favourable for their nondisintegration.

There is also a large coal district on the South Saskatchewan, about Medicine Hat; some of the seams can be seen cropping out almost horizontally, on the banks of the river, a few miles above the latter place. But probably the most important coal deposit in the North-West is that of the "Coal Banks," on the Belly River (one of the main tributaries of the South Saskatchewan), twenty-five miles east of Fort M'Leod and about one hundred and twenty miles south of Medicine Hat. Here the seam is about nine feet thick, and dips at a very low angle to the west. This locality is now being actively worked by Sir A. T. Gault. The coal is taken in barges and steamers to Medicine Hat; hence it is distributed east and west along the line of railway: it is a fine semi-bituminous coal, containing a little pyrites, and not unlike some Welsh steam coals: it appears to be admirably adapted for steam-engines and domestic purposes, and is being used on the locomotives of this section of the railway, and also on the steamers plying between Medicine Hat and the mines; it produces a very hot fire, and forms very little clinker or cinder.

Besides the localities above mentioned many others are known, especially in the district to the north; to the east, on the Souris plain, the beds are much more lignitic in character than to the west.

Although it is only quite lately that these coals have been extensively used throughout the country, they have been employed to a limited extent, for some time past by the North-West Mounted Police and by the pioneers of the district; yet it seems highly probable that, on the development of the mines, and extension of the railway, these coals will not only be almost exclusively used throughout the territory, but that there will be a large export trade to other districts.

XXVIII. — THE PHOSPHORITE NODULES OF PODOLIA —
 NOTES BY J. P. O'REILLY, Professor of Mining and
 Mineralogy, Royal College of Science, Ireland.

[Read, March 17, 1884.]

At a recent Meeting of the Natural Science Section of the Royal Dublin Society, Professor Valentine Ball submitted for examination, and made some remarks on, specimens of the globular or spherical concretions of Phosphorite imported into this country from Podolia, in southern Russia. Their singular form, their remarkable size, and radiated fibrous structure, excited curiosity and discussion as to their origin. Wishing to arrive at some solution of the problem thus apparently presented, and assuming that a mineral of this remarkable character and of such industrial importance must have undergone chemical investigation and been scientifically noticed, I had recourse to the authorities at hand in the College Library, and was enabled to get from them a sufficiently detailed account of the mineral itself, of the nature of its deposits, and its probable origin. At the same time I received, through the kindness of Mr. N. Stadnicki, son of Count Stadnicki, on whose estates in Podolia large deposits of this mineral exist, a fine collection of the balls in different states, which enable me, I consider, to push the question a stage further than that arrived at in the memoirs which I am about to cite.

The first notice which I met with was the excellent article on Phosphorites, forming one of the parts of the *Encyclopédie de Chimie de Fremy* (tom. v., 1st section, 2nde partie, p. 89), wherein the locality of the deposit is noticed and a summary given of a memoir on these phosphorites, by Fr. Schwackhöfer, published in the *Jahrbuch der Kais. Kön. Geolog. Reichsanstalt*, 1871, xxi. Band, p. 211. This memoir is very complete, and accompanied by plates. He opens by explaining that the Silurian formation, which extends over a great part of Northern Bukovina and Russian Podolia, is mainly represented by compact and highly fossilised limestones and clay slates. Directly on these rest regularly stratified beds of

chalk—sometimes those containing flints, known in the country by the name *opoka*; sometimes the green sands.

The silurian slates present two very distinct forms—the one large, grained and compact, with rough surfaces, greenish-brown colour, giving rise, by splitting, to thick flags; the other, slaty in its texture, is composed of thin, even, greasy, lustrous, and friable plates of a greenish-black or, more rarely, greenish, colour. This latter form is that occurring in Russian Podolia, and is characterised by its greater tendency to weathering, giving rise to more rounded outlines of country. The first-mentioned clayslates produce in the valley of the Dneister and its confluent very abrupt banks, sometimes almost perpendicular. The thickness of these clayslates is of several hundred feet. It is in the greenish-black and thin-plated clayslates that the globular phosphorite is exclusively found, these beds being, according to Blöde and Barbot, referable to the Silurian formation.

The phosphorite balls are interstratified with these slates, often in great quantities. Owing to the tendency to weathering of the slates, the balls give rise to secondary deposits, such as the detritus heaps of the chalk beds, and are found thus along the banks of the Dneister, even far into the river bed.

The localities marked by the more frequent occurrence of the phosphorite balls are situated on the left bank of the Dneister, in the zone of country lying between *S^{ta} Uszica* and *Mogilew*. Very fine surface deposits are met with at *Zurczewka*, *Kaljus*, and *Ljadowa*.

The mineralogical characteristic of the Podolian phosphorite is, that it occurs, almost without exception, in a spherical or globular form, showing an inner concentric radiated structure.

The surface is uneven, often foliated, feels greasy, and presents a dark-green colour, somewhat like that of fresh cast iron. The balls, disengaged from the matrix by erosion, and having undergone abrasion, present a bright-grey and even surface.

The diameters vary from 2 cm. to 16–18 cm., generally 5–6 cm. The density is from 2.8 to 3. The hardness about that of fluor-spar.

The radiated structure is not in all cases the same: in some this structure is more marked towards the periphery, becoming indistinct towards the centre, where it appears compact; the core

at the centre being in this case of crystalline foliated calcspar of a bright-grey or greyish-brown colour, showing generally a star form. In others the radiated structure is equally distinct all through, and at the centre is found a star-formed hollow space, filled with a brown earthy mass. The former generally presents a more greyish colour; the latter a very distinctly brown colour. Between the radiating fibres or bands occur various enclosed minerals, such as calcite and plates of pyrites, little grains of quartzite, small quantities of a yellow powder, composed of manganese carbonate, a dark-brown pulverulent mass, which is a mixture of iron oxyde and carbonate of iron, and finally an aluminous silicate in the form of a white earthy mass. Occasionally particles of galena occur sprinkled through the mass.

Several Tables of Analysis are given, one of which gives in constituents the composition of the inner and outer zones of the specimen analysed; another that of the core or kernel; and another that of the matrix of the phosphorite, which shows whence the phosphoric acid proceeded.

I.—CONSTITUENTS OF THE OUTER AND INNER ZONE OF A COMPLETELY-ALTERED PHOSPHORITE BALL OF 15 cm. DIAMETER.

	Outer Zone.	Inner Zone.
Tribasic lime phosphate.	79.70	87.61
Phosphoric acid,	0.03	0.29
Calcium fluoride,	6.16	7.29
Calcium carbonate,	0.68	0.61
Sesquioxide of iron,	2.65	1.06
Manganese hyperoxide,	—	0.57
Lime silicate,	0.26	—
Soda silicate,	0.46	—
Alumina silicate,	3.99	1.01
Silica,	4.54	0.32
Organic matter,	1.39	0.79
Water,	0.72	0.53
Total,	100.58	100.08

II.—CONSTITUENTS OF THE CORE, THE MIDDLE AND OUTER ZONE OF AN INCOMPLETELY-ALTERED PHOSPHORITE BALL OF 15 CM. DIAMETER.

	Outer Zone.	Middle Zone.	Core.
Tribasic lime phosphate,	82.66	83.33	53.70
Phosphoric acid,	0.03	0.43	0.96
Calcium fluoride,	6.42	6.85	4.58
Lime carbonate,	1.95	5.27	37.02
Pyrites,	1.08	—	—
Ferric oxyde,	1.24	1.80	1.35
Potash silicate,	0.51	0.33	0.24
Soda silicate,	0.67	0.44	0.32
Alumina silicate,	0.55	—	—
Silica,	2.63	0.87	0.25
Organic matter,	1.60	0.89	0.78
Water,	0.57	0.38	0.31
Total,	99.91	100.59	99.51

III.—MATRIX OF THE PHOSPHORITES, SILURIAN SLATE ROCK OF ZURCZEWKA.

	Soluble and Insoluble Parts in Hydrochloric Acid in 100 parts.		Sum.
	Soluble.	Insoluble.	
Ferric oxyde,	4.78	1.58	6.35
Ferrous oxide,	2.70	Traces.	2.70
Manganese oxyde,	—	—	Traces.
Alumina,	8.86	12.68	21.54
Lime,	1.47	Traces.	1.47
Magnesia,	1.11	0.41	1.52
Potash,	1.23	1.83	3.06
Soda,	0.21	2.03	2.24
Silica,	Traces.	55.36	55.36
Carbonic acid,	0.42	—	0.42
Phosphoric acid,	0.33	—	0.33
Sulphuric acid, chlorine, fluorine,	—	—	Traces.
Organic matter,	—	4.06	4.06
Water,	1.35	—	1.35
Total,	22.46	77.99	100.40

Schwackhöfer details fully and discusses the method of analysis followed, and the appropriation of the elements found, to the constituents mentioned in the Tables, and shows, from the comparison of Tables I. and II., that the lime phosphate of the Podolian phosphorites stands in relation to the calcium fluoride in exactly the same ratio as occurs in apatite, and that therefore we may admit that the mode of formation is the same as that of apatite. He demonstrates this by a Table.

He further shows that between the apatite constituent and the lime carbonate of the inner bands of the phosphorite there is a constant ratio, the sum of the two constituents being a constant, as is shown in the accompanying Table:—

	I.	II.	
	Inner Part.	Middle Part.	Core.
Lime phosphate,	94.90	90.18	58.28
Lime carbonate,	0.68	5.27	37.02
Totals,	95.58	95.45	95.30

As regards the surface coating this relation does not hold, on account of the presence of incorporated foreign bodies.

The author then proceeds:—"From the foregoing data, as to the nature of the deposit, mode of occurrence, and chemical constitution of the phosphorite, sufficient ground is afforded for answering the question, *How have these phosphorites originated?*"

The opinion received up to then, and put forward by the author, had been, that these concretions were originally formed of carbonate of lime, which was altered into phosphorite by the phosphoric and fluoric combinations washed out of the slate rocks. This opinion he now, to a certain extent, modifies.

He considers that the material for the formation of the calcite concretions (specimens of which he found composed of finely crystalline calcite, with some phosphoric and silicic acid, the calcite being always at the core and concentrically formed round the centre) was furnished undoubtedly by the chalk marl (opoka),

which ordinarily overlies the phosphorite deposits in thick beds, or the former existence of which is at least proved by the remaining flint nodules.

The washing out of the lime by rain charged with CO_2 , and the passage of the lime carbonate into the underlying beds, is, he says, easily explainable, as also the separating out of this bicarbonate as simple lime carbonate, and the concentric layering of the simultaneously formed lime particles around the previously formed core, with intervention of a lime silicate as a cement. That the process was gradual is shown by the shell-like structure of the concretions, as also by the apparent crushing of the slates in contact with the balls. He further shows that the assumption that elements requisite for the transformation of the lime carbonate into apatite proceeded from the slate is not a mere guess, but is sustained by the analyses of the mother rock, wherein phosphoric acid in determinable quantity is shown to exist, as also traces of fluorine. He attributes the clefts in the "completely infiltrated balls" (in which there is no calcite kernel), as also the radiated structure of the phosphorite, to a *contraction* of the matter consequent on the metamorphosis of the calcite balls of crystalline granular texture. This contraction had for consequence the change of texture from finely granular into radiated fibrous; and he enters into an examination of the volume ratio between the calcite and subsequent apatite. This explanation supposes that the phosphoric acid penetrated the calcite balls from outwards inwards in solution (as acid lime phosphate); that thus the tenor in calcium, which for apatite is 39.68 per cent., and for calcite 40 per cent., that is, nearly the same, remained unchanged during the metamorphosis; and he cites experiments to prove this.

In the main, therefore, Mr. Schwackhöfer considers that the origin of the nodular phosphorites was the metamorphism of nodules of calcite into apatite. But it remains to be shown that such calcite nodules are usually to be found in Silurian slate-rocks, or that calcite usually occurs in that form: furthermore, that a change from a compact texture to a radiated fibrous structure, such as is shown by the phosphorite, is admissible in this case, or explainable by change of volume and contraction.

The examination of the samples received from Podolia, through Mr. N. Stadnicki, seems to me to point to another and less imme-

diate origin. Amongst those specimens are pieces of balls entirely composed of iron pyrites: one of these pieces is distinctly marcasite, or liver pyrites, the characteristics of which are so well known. Moreover, while pyrites occur in nearly every rock, marcasite is more particularly associated with marls and clay beds, and in this respect the observation of Mr. C. Mène (C. R. lxiv. 867), cited by Dana in his 5th edition, p. 800—that the pyrites of unaltered sedimentary beds is mostly marcasite, while that of metamorphic rocks is ordinary pyrites—is interesting and to the point. If now we consider a bed of clayslate, in which originally marcasite nodules were developed, these, by subsequent changes of sea level, superposition of chalk-marl beds, and slow infiltration of solutions containing carbonic acid and other constituents taken from the chalk marls into the underlying slate rock, would undergo transformations which might result at a certain stage in calcite; and then the subsequent changes would be explainable in the way pointed out by Mr. Schwackhöfer. The examination of a nodule of marcasite or liver pyrites undergoing decomposition points to this solution, since it shows not merely a radiated fibrous structure exactly as that of the phosphorite balls, but also a change of volume consequent on the formation of sulphate of iron. This change is an increase; the mineral is therefore rent, and presents clefts exactly as those occurring at the centre of certain of the nodules of phosphorite. The hollowness of these clefts, or the absence of contained matter, is easily accounted for, since these clefts would be filled by the iron salt, and this would be the last removed, if the action proceeded from the periphery towards the centre, and would either be replaced by another mineral, if the solution could give anything, or would simply be removed by the passage of water. There would not, therefore, have been contraction, but rather the contrary increase of volume, which precisely rendered the mineral more apt to give passage to subsequent infiltration and metamorphism. As to the series of changes having led up to apatite, it is presumable that it was more complex than that assumed by Schwackhöfer, who starts with calcite nodules.

Starting from marcasite nodules, the clefts would tend to show that change to sulphate of iron took place first, and that it was complete. It must be borne in mind that these nodules, being entirely enveloped by clay more or less plastic, were protected

from disintegration, and that subsequently the iron was replaced by lime, giving rise to gypsum, which could in turn give rise, by metamorphism, to calcite, and this to apatite.

What must be borne in mind in a case like this is, that the series of geological changes which took place in the country of the deposits must have been closely connected with these pseudomorphisms; and that the fact of the beds having undergone great variations of level, with change of pressure, change of temperature, change of permeating solutions, both as regards constitution, concentration, temperature, and pressure, the final state and products which we examine must be the resultant of all these actions.

That the pyrites still remaining in the beds are still undergoing decomposition would seem to be shown by the existence of chalybeate springs in the district. How far this would point to a stage of change, wherein the sulphur was removed as sulphuretted hydrogen, is a question to be discussed. Organic matter is shown to exist in the balls, and such organic matter would be highly conducive to this process of removal. Furthermore, relatively small quantities would produce this result if caused to pass continuously through the nodules, so that what would finally remain after complete removal of the sulphur would be seemingly insignificant.

There is a last remark to be made, from a practical point of view, relative to this change of marcasite into apatite: it is, that indications of marcasite would *pro tanto* be possible indications of phosphorite deposits, and would therefore serve as a guide for their research.

XXIX.—ON THE GENERATIVE AND URINARY DUCTS IN
CHITONS. BY ALFRED C. HADDON, M.A., M.R.I.A.,
Professor of Zoology, Royal College of Science, Ireland.
(Plates X. and XI.)

[Read, April 21, 1884.]

Generative Ducts.—There is as a matter of fact nothing especially remarkable about the generative organs of Chitons. Cuvier (1), Middendorff (2), Von Jhering (6), &c., describe paired generative ducts arising from the median unpaired generative gland. The oviducts arise, according to Haller (11), in *Chiton siculus* and *Ch. fascicularis* from a dilated and folded uterus, which is situated at about the hinder third of the ovary on the *ventral* side. Sedgwick (8) (*Ch. discrepans* and *Ch. cancellatus*) does not state whether the ducts arise from the dorsal or the ventral side of the generative organ. Van Bemmelen (12) mentions that the efferent duct in *Ch. marmoreus* and *Ch. marginatus* springs from the *dorsal* side, and my own investigations on various forms agree with the latter statement. The ducts take a more or less direct course to the gill-row, and usually open near the fourth or fifth gill, counting from the posterior end. Hubrecht (10) has confirmed by sections “the presence of the same arrangement in *Ch. marginatus*.” Sedgwick (8) states that “the male duct has a short direct course to its opening; while the female duct is much coiled.” This, at all events, is not the universal case. According to Sedgwick and Haller (11) the duct curls round the upper border of the lateral nerve cord, between it and the gill vein, and thus opens to the exterior, internal to the gill-row.

Dall in a short Paper, published in 1874 (5), states that in 1869 he had noticed the fact that the ovarian openings are not invariably simple apertures. Their position had been previously known, but it is not uniform in all Chitons. In some the fenestræ are close to the anus, and single on each side. In describing the orifices of *Ch. ruber* (Lin.) he says, “The ‘cancellated space,’ noticed by Mr. Emerson (as per notice in Ann. Mag. Nat. Hist., Mar., 1874), on each side, behind the branchiæ, is a fold or groove containing the ova-

rian fenestræ (Mr. Dall illustrates his statement with a diagram). There were in this specimen three fenestræ on each side, but, according to Dr. Carpenter, the number is variable,¹ Prof. Verrill having counted from four to six in some specimens. These fenestræ are more complicated than in most Chitons which I have examined. I have never been able to satisfy myself that there is a true oviduct (opening externally),² and it may be that the ova are dehiscant in the perivisceral cavity, and may be expelled through the fenestræ, as they are through the analogous 'oviducts or segmental organs' of brachiopods."

Dr. Carpenter (4) says, "in the genus *Stimpsoniella*, as in *Trachydermon* (the genus to which *Ch. ruber*, *albus*, *cinereus*, &c., belong), the fæces are expelled through slits close to the caudal lobe, one on each side." It is strange that this able systematic conchologist should have overlooked the anus, and have mistaken the orifices of the oviducts for openings of the alimentary canal and ova for fæces!

In another paper Dall (7) states of the following species—*Ch. (Trachydermon) albus*: "Ovarian openings, single on each side, the posterior end of the gill-row passing behind them. The oviducts, as in some other species, could not clearly be made out." *Ch. marmorea* (Fabr.) "Oviducts not made out. Ovarian openings simple, and close on each side of and a little behind the anus, from which a ridge extends in front of them on each side. But there appear also to be two openings in the vicinity of the fourth or fifth branchia from the posterior end of the gill-rows, one on each side. The contracted condition of the specimens, from the effect of the alcohol in which they were preserved, prevented a satisfactory confirmation of these appearances." *Ch. submarmorea* (Midd.)—"Soft parts very similar to last in every respect, except that the

¹ I find that in the *Ann. Mag. Nat. Hist.*, 1874, Dr. P. P. Carpenter says (p. 121):—"Mr. Emerton first observed a great peculiarity in the animal—that there is a cancellated space between the posterior gill and the caudal extremity. Professor Verrill observed that in different specimens there were either one, two, or three rows of holes on each side. The caudal lobe is generally figured as an anal tube; but in *T. rubrum* (*sic*) it is an imperforate muscle, working the posterior part of the girdle. The fæces were distinctly seen to escape, sometimes on one side, sometimes on the other, as it appeared to me, from a slit on each side."

² This was added in ms. in the copy of the Paper Mr. Dall kindly sent me.

openings near the anus were absent. The specimen was a male. Some of these differences may be sexual: at all events, the subject requires investigation from living specimens." *Ch. trifida*.—"No ovarian openings could be detected." *Ch. australis*.—"The ovarian openings situated close on either margin of the anus." *Ch. wossnessenskii* (Midd.)—"No distinct oviduct could be observed." *Ch. imporcata* (Carp.)—"No oviduct could be traced though the ovary was crowded with eggs." *Ch. vestita* (Sow.)—"The 'ovarian' openings, bilaterally symmetrical, are situated just behind and, as it were, under the shadow of the posterior branchia on each side. They are not simple orifices, but fenestræ, composed of two openings somewhat oblique and linear; the anterior a little nearer the girdle, and a little larger than the posterior one." *Chitonellus fasciatus*.—"There seemed to be two oviducts leading from a single ovary to small orifices, one on each side of the anus." In a few other species Dall has identified the normal arrangement stated above at the commencement of this Paper.

I have recapitulated Dall's statements, in order to show the great difficulty there is in making out certain details of the internal anatomy simply by dissection of spirit-hardened specimens. If it had been possible to sectionize these examples, the relations of the generative ducts would have been elucidated; and, for the future, it appears to me, we must be cautious in admitting the absence of generative ducts in Chitons till we have microscopical evidence to prove it.

My own observations on the oviduct of *Ch. ruber* call for little comment. The duct arises on the dorsal wall of the ovary, near its posterior end, as a dilated, ciliated, or rather flagellated sack, which at first runs parallel to the gland, and then diverges outwardly, narrowing into a circular oviduct, lined with ciliated cubical cells, and possessing a large lumen. This pursues a straight course outwards, being slightly directed backwards, and ends with tumid folded lips, between the foot and the branchial vein, about the level of second and third gill, counting from behind.

The general nature of this duct will be seen on reference to figure 1, plate X., which is a camera-lucida drawing combined from one or two consecutive sections, and is not an ideal diagram. The state of preservation prevents me from adding those histological details which I should wish.

Fenestral Glands. — The above-mentioned “cancellated spaces,” or fenestræ are the expression of somewhat complex glandular infoldings of the epidermis in those regions, for which I propose the provisional name of “Fenestral glands.”

Each “cancellated space” extends, transversely, from that spot where the upper surface of the foot joins the body proper outwardly as far as the longitudinal fold on the underside of the mantle¹; and longitudinally it extends from just in front of the anus to about the region of the renal duct, and therefore some little distance behind the generative orifice. The extent of the area and the complexity of the gland appear to vary considerably in different specimens of the same species.²

The epidermis of the ventral surface of the foot is composed of columnar cells; these become somewhat shorter on its upper surface, and in the region in question again become markedly columnar, and very large in size. They resume their ordinary character in passing over the longitudinal fold; and external to it they secrete the calcareous spicules characteristic of the species.

The gland simply consists of the epidermis, composed of large columnar cells of the definite areas above mentioned, which is thrown into a number of folds, or produced into slightly contorted and branched tubes, thus giving a remarkable labyrinthine appearance to transverse sections of that region of the body. Between the variously cut sections of these tubes are small patches of polygons which are, of course, merely the transverse or oblique sections of the cells or other cæca of the gland. See figures 2-4, Plates X. and XI.

It would be premature at present to discuss the nature of these curious infoldings: in the allied *Ch. cinereus* they appear to be inconspicuous, and to be absent or rudimentary in other forms.

Dr. Hubrecht (9) has described a pair of simple cæcal glands in *Proneomenia sluiteri* (Hbrcht.) which open into the anal cavity, and which secrete extremely delicate threads; anteriorly they are enclosed in a strong muscular investment. Hubrecht suggests they

¹ This fold is the “fringe” or “true mantle edge” of Dall (7), and the “longitudinal fold” or “lateral band” of Haller (11).

² For example, in all my specimens of *Ch. ruber* from Norway the gland is much infolded; but in a specimen from “Eastport, N. E. America” (for which I am indebted to the courtesy of the Rev. A. M. Norman), the gland is a great deal simpler.

may be compared with a byssus organ of very primitive construction, or may prove to play some accessory function subordinate to the secretion of generative materials.

The same organ, although in a much less developed condition, was found by Hubrecht in *Neomenia*; the muscles, too, are nothing like so well developed as in the former genus.

It is possible that these glands of the *Neomeniæ* may be homologous with the glands in question. The difference in position need prove no difficulty, since it would be only another example of the tendency of certain terminal organs in the *Amphineura* (such as the branchiæ, excretory, and generative ducts) to extend along each side of the body. A greater difficulty exists in a comparison of the structure of the glands themselves; but this I will leave for the present, till I am able to state how they occur in other species of *Chitons*.

Kidneys and their Ducts.—Until Sedgwick's investigation in 1881 (8), our knowledge of the structure and relations of the kidneys of the *Chitons* was of the most unsatisfactory and contradictory kind possible.

Middendorff (2) figures and thus describes, in *Ch. stelleri*, a gland which he identified as the kidney:—"To the naked eye it appears as a very broad velvet-like covering on the shining tendon-mass of the ventral muscles; the middle area only of the ventral body-wall is left free; the sides of it, however, and a portion of the lateral wall of the body-cavity are covered in the form of a horse-shoe; each limb of this horse-shoe arises close behind the anterior diaphragm, proceeds backwards, and unites with its fellow in a closed arch on the front wall of the posterior diaphragm." The gland itself is stated to consist of a longitudinal canal beset with ramified cæca. The whole structure is very delicate, and possesses extremely thin walls. The Russian naturalist gives no account of the histology of the gland, and is careful to add that he was unable to discover its external opening or its relation to the other viscera.

Schiff (3) could not find this gland in *Ch. piceus*, and throws doubt upon Middendorff's interpretation.¹

¹ I have roughly dissected a *Ch. piceus* from the Barbadoes, and have seen the kidney, but I have not yet made out its relations.—A. C. H.

Von Jhering (6) assumes that Schiff has demolished Middendorff's account, and asserts that "a kidney was unknown in Chiton until now." He thus defines the newly-discovered (!) organ: "The kidney is a tree-like ramified gland, lined with a ciliated epithelium, lying upon the floor of the body-cavity; it possesses an unpaired median efferent duct, which opens below the anus." The form dissected was *Ch. fascicularis*. Mr. W. H. Dall informs me that, in a letter to him, Von Jhering writes that the posterior median opening of the kidney was an error of observation on his part; and Hubrecht (10) states that "Dr. Brock, of Göttingen, kindly writes to tell me that Von Jhering has lately withdrawn this view, as reposing on an erroneous observation, and has been convinced of the presence of lateral renal openings (prior to Sedgwick's exhaustive researches)." Dall (7) "did not detect the renal organ in some cases, and failed to find any excretory opening." He goes on to say, "It is probable that this exists, but the contraction of the tissues of my specimens by alcohol may have obliterated it."

Sedgwick (8), in a preliminary Paper,¹ entirely and successfully disproves Von Jhering's statements, and found that "Middendorff's observations, as far as they went, were perfectly correct." The species he examined were *Ch. discrepans* and *Ch. cancellatus*; the former species being so closely allied to *Ch. fasciculatus* that it practically amounts to re-examination of Von Jhering's species. The kidney is a paired dendritic gland (figs. 1 and 2),² with an external opening into the pallial groove, and an internal pericardial orifice; it lies on the side of the floor of the body cavity. Each gland consists of a longitudinal duct, beset with branched glandular cæca; about the level of the last six gills this duct is swollen into a "bladder-like structure," which, at its posterior end, sends out a small tube, and at right angles to itself, which opens to the exterior in the pallial row, and the level of the last (16th) gill. About the level of the fourth shell-plate there is a second tube, which turns sharply round, and runs back more or less parallel with, but above and internal to, the former. It is at first also furnished with glandular cæca, but

¹ I understand that he is not intending, for the present at all events, to continue his investigations.

² I am enabled through the kindness of my friend Mr. Sedgwick, and by the permission of the Royal Society, to introduce Mr. Sedgwick's original diagrams (Figs. 1 and 2) in illustration of his views.

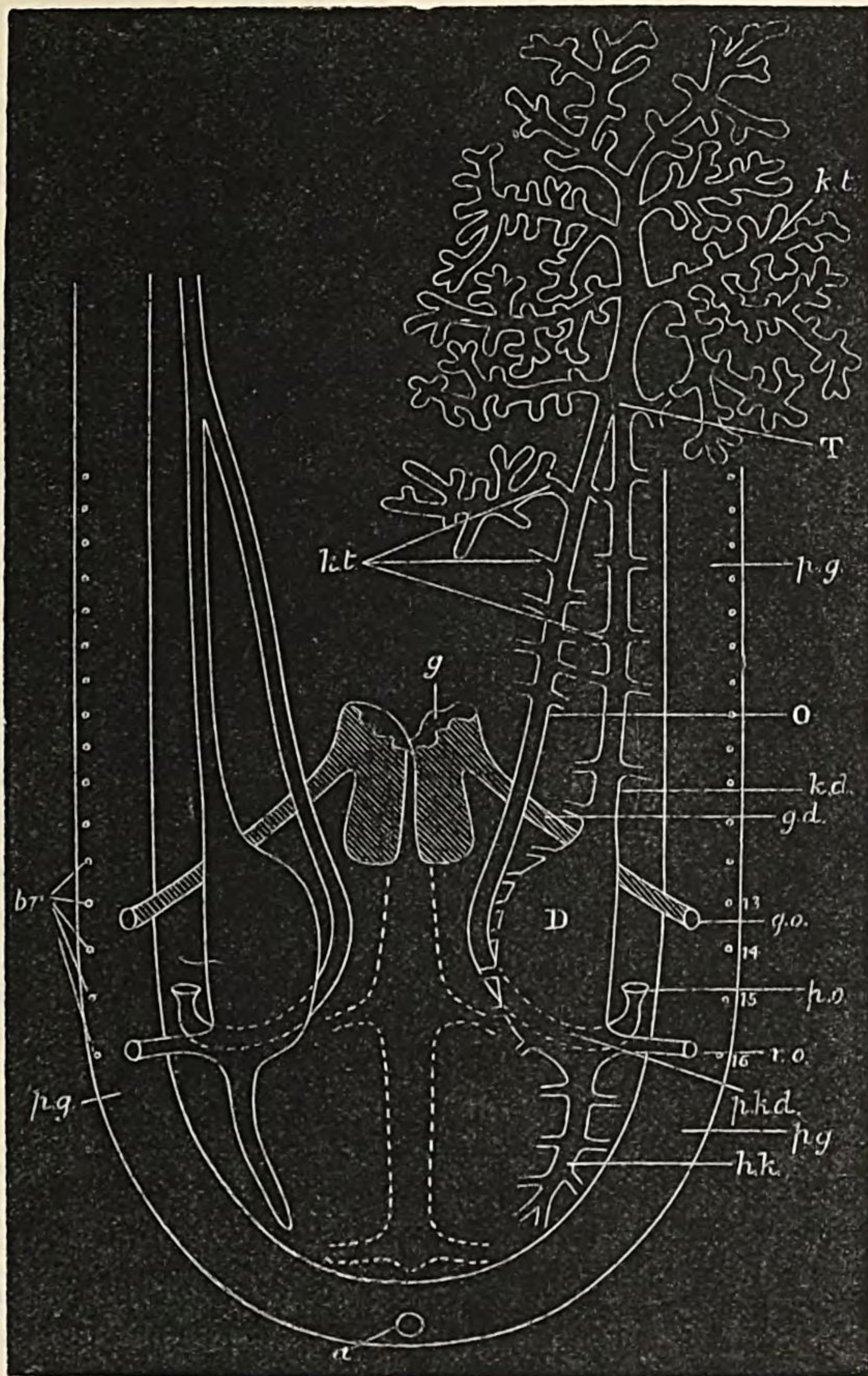


FIG. 1.

A diagrammatic representation of the kidney and generative ducts of *Chiton discrepans*, viewed from the ventral surface. The branched nature of the kidney is shown in the anterior part of the figure on the right side; posteriorly these secreting tubules are omitted. On the left side of the figure the kidney duct alone is indicated.

a, anus; *br.*, the 16 branchiæ; *D*, dilated part of kidney duct opening to exterior; *g*, generative gland, the greater portion of which is removed; *g.d.*, generative duct; *g.o.*, generative orifice; *h.k.*, posterior part of kidney duct; *k.t.*, secreting tubules of kidney; *k.d.*, duct of kidney running forward, bending round at *T* and running back, receiving glands as far back as *O*: from *O* it runs to the pericardial opening *p.o.*, receiving no glands; *p.g.*, pallial groove; *r.o.*, renal orifice; 13, 14, 15, 16, last four gills; the ventricle and auricular openings are indicated by dotted lines.

from the level of the fifth shell-plate to its posterior termination it is devoid of them. On reaching the hinder border of the bladder-like dilation of the kidney duct first described, it runs outwards and then forwards, in close contact with the dorsal side of the lateral nerve cord. At the level of the penultimate gill it opens by a small pore into the pericardium, beneath the anterior part of the auricle.

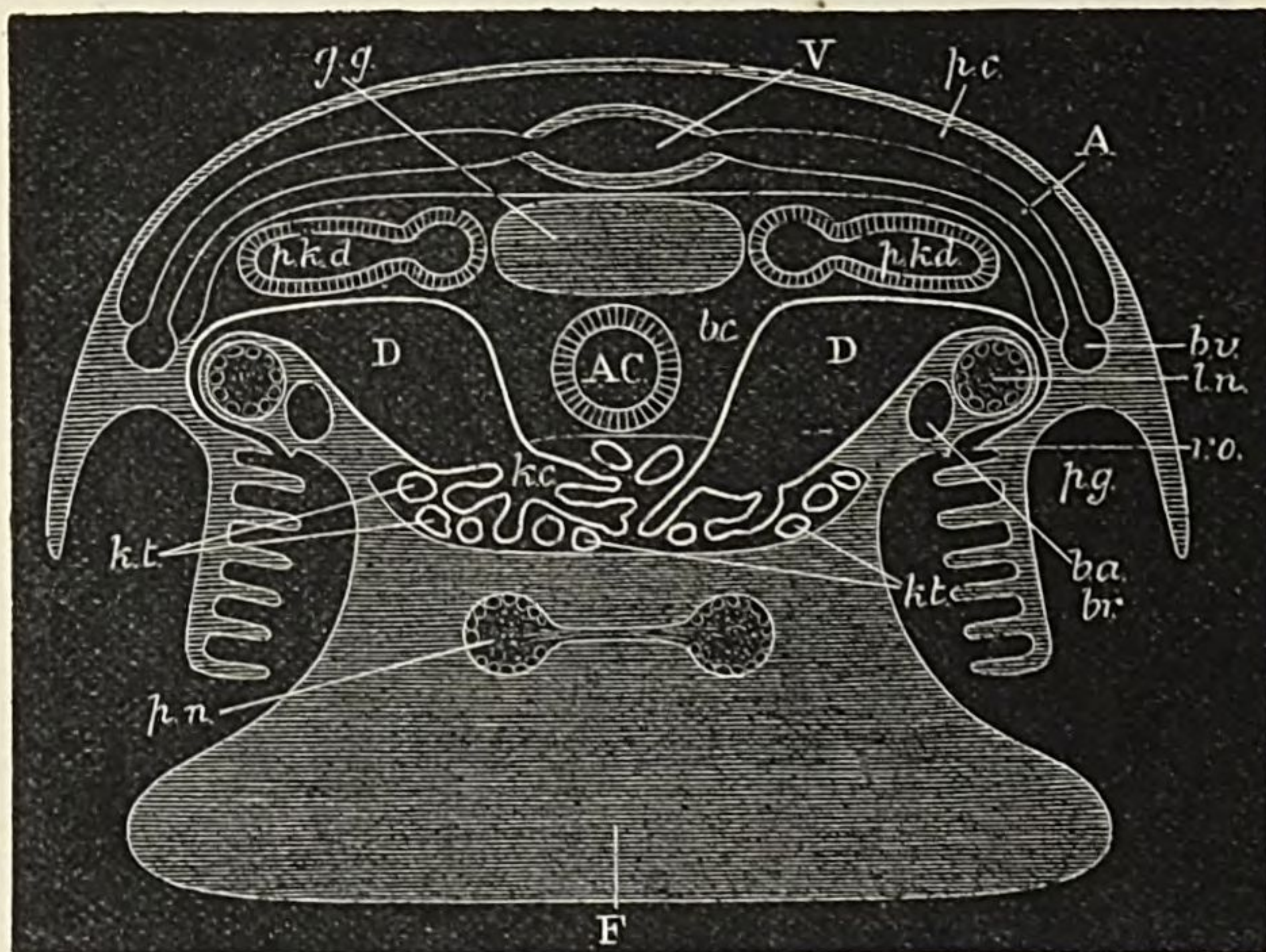


FIG. 2.

A diagrammatic representation of a transverse section through *Chiton discrepans* at the level of the renal orifices. The dorsally situated pericardial cavity is separated from the general body cavity by the pericardial floor. The posterior, apparently median unpaired part of the kidney, seen by von Jhering, lies on the floor of the general body cavity. A little in front of this section the kidney tubules take up a distinctly lateral position.

D, *p.g.*, *b.r.*, *k.t.*, *r.o.*, as in Fig. 1; A, auricle; A.C., alimentary canal; *b.a.*, branchial artery; *b.v.*, branchial vein; *b.c.*, body cavity; F, foot; *g.g.*, generative gland; *k.c.*, opening of kidney tubules into dilated part of kidney duct; *l.n.*, lateral nerve cord; *p.n.*, pedal nerve cord; *p.c.*, pericardium; *p.k.d.*, part of kidney duct which is hidden from view by D in Fig. 1; V, ventricle.

The recurrent internal kidney duct, which receives no glandular cæca, is, with the exception of a small portion adjoining the pericardial opening, lined by columnar cells containing a brownish-yellow colouring matter, which renders this portion of the duct easily visible to the naked eye. The part of the duct which runs forwards from the level of the hinder edge of the bladder to the

pericardial opening is lined with large columnar cells, which line also the pericardial opening.

Haller (11) refers to the great difficulty in the study of this organ on account of its colour and delicacy. He finds that in the two species he examined (*Ch. siculus* and *Ch. cajetanus*), the sulphur-yellow-coloured kidneys are paired acinose glands (fig. 3).¹ "We find on each side a wider portion, which we will call the kidney-body ('Nierenkörper'), and which is in reality nothing more than a wide tube into which the more or less compound flaps open separately. It extends from the hinder end of the first 'shell-scale' to about the middle of the last; the flaps opening into the kidney-body throughout its length." These flaps may be divided into two groups—the longer and shorter. The latter densely beset the anterior portion of the kidney-body on all sides; in the hinder region, however, the upper surface is nearly free from them. The larger flaps, which are very long, are only slightly ramified; they are grouped separately at fairly constant points, and only open mesially, and on the under side of the kidney-body, except at the hinder end. These long flaps are arranged in eight brush-like groups, corresponding to the hinder border of each shell. The flaps of one side often overlap

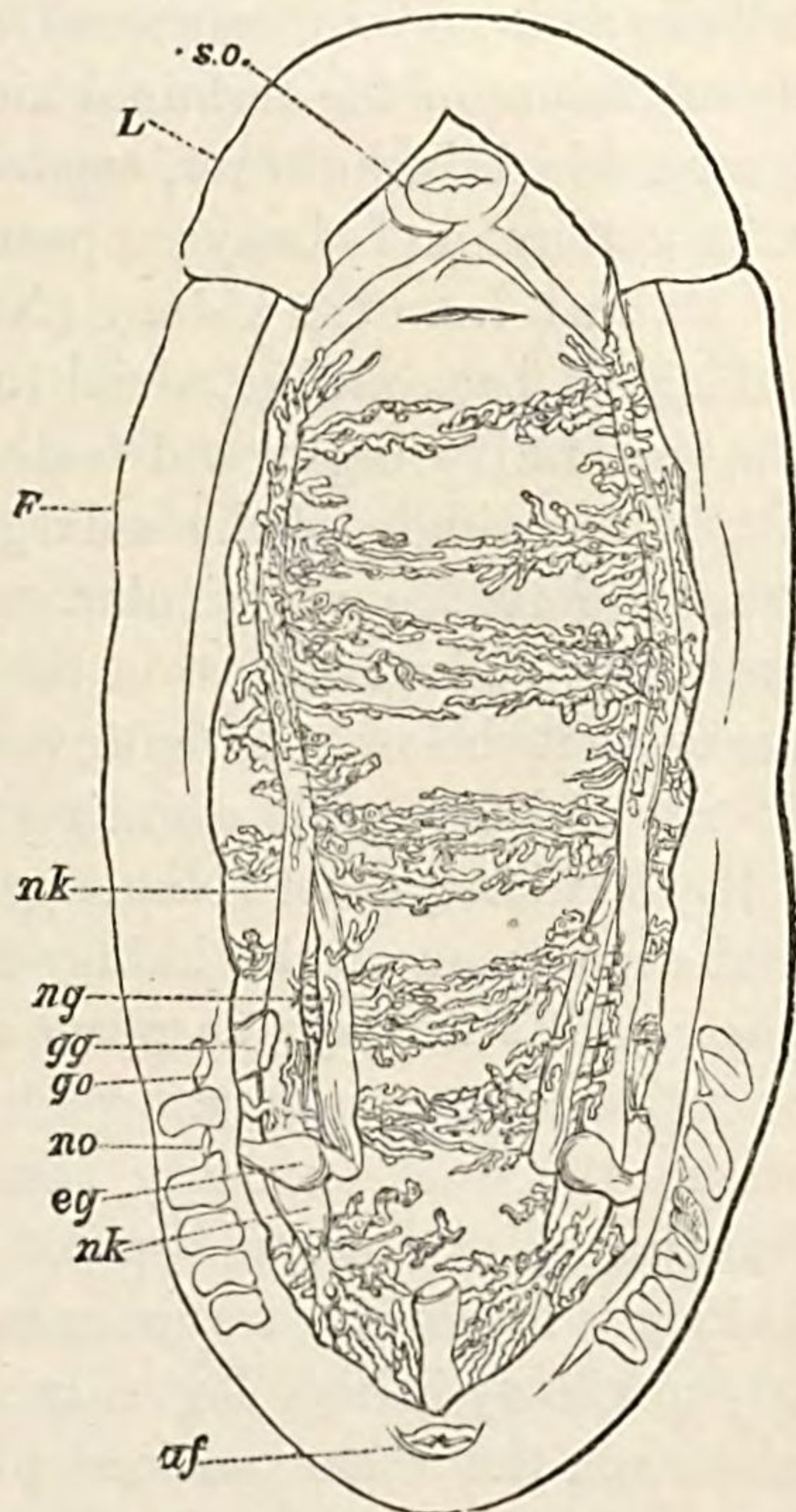


FIG. 3.

Dissection of the renal organs (nephridia of *Chiton siculus*, after Haller (11). *F*, foot; *L*, edge of the mantle not removed in the front part of the specimen; *s.o.*, oesophagus; *af*, anus; *gg*, genital duct; *go*, external opening of the same; *eg*, stem of the nephridium leading to *no*, its external aperture; *nk*, reflected portion of the nephridial stem; *ng*, fine cæca of the nephridium, which are seen ramifying transversely over the whole inner surface of the pedal muscular mass.

¹ Fig. 3 is reproduced, by permission of the publishers, from Fig. 15 of Professor E. Ray Lankester's article "Mollusca," in the last edition of the *Encyclopædia Britannica*.

those of the other across the median ventral line; but there is never any structural junction.

The kidney-body itself lies in the lateral body-wall, and in its histological and physiological structure it agrees with that of the flaps. Our author, however, denies that the efferent duct arises from the posterior enlargement of the kidney-body. In a footnote he adds:—"In transverse sections a small forwardly-projecting diverticulum of the terminal kidney duct can be seen (Nierenendgang), which is, however, separated from the pericardium by thick musculature, and always appears as a *short blind process*."

A duct from the kidney (Nierengang) arises behind the fourth tuft, runs backwardly mesial to the glandular body, at first under the generative organ and further behind under the pericardium to about the middle of the enlargement of the kidney-body. Somewhat before the ventricular end of the heart it suddenly bends outwards, and passing over the kidney-body and above the lateral nerve, but below the gill vein, opens externally between the fourth and fifth gills counting from behind. This duct, which he calls the kidney-duct (Nierengang), is constructed like the kidney, and even some of the kidney-flaps open into it anteriorly. It at once strikes the eye as often appearing injected with the brown secretion of the kidney. "The brown colour ceases at the spot where the duct suddenly turns outwards; and then one could imagine, if one is predisposed, that there is an opening of the kidney into the pericardium in Chitons." This terminal portion of the kidney is histiologically very different from the kidney, and also from the other portions of the efferent duct. The latter is lined with a low cubical ciliated glandular epithelium. The former, however, close to its opening into the brown-coloured portion, has a three-fold higher cylindrical epithelium, with flagella four or five times the length of the cells. The height of these cells diminishes gradually towards the exterior, but ends abruptly in a wall-like manner where the efferent duct enters the kidney duct.

"The internal opening of the kidney, possibly into the pericardium, as occurs in other Gasteropods, does not exist. We must rather assume that, until some one shall have described the development, an internal opening, or ciliated funnel, existed in late larval stages, which in the adult animals has entirely closed, and has so far been metamorphosed that it is no longer recognizable.

I have the verbal information of Dr. B. Hatschek that this is not unique of its kind, since the ciliated funnel of *Sipunculus* exists at first, and is degenerated in a later larval stage."

Van Bemmelen (12), in order to test the above results, studied *Ch. marmoreus* (Fabr.), *Ch. marginatus*, and *Chitonellus fasciatus*, and found, "with all desirable clearness, the opening of the kidney into the pericardium, described by Mr. Sedgwick," and confirms the latter's account of the general structure of the kidney, and necessarily at the same time casts doubt upon Haller's interpretation. He believes that Haller has confused the external duct with the pericardial duct. The latter holds that the terminal portion of the kidney duct, directly it turns at right angles to lead to the exterior, is lined with flagellate cells, which very shortly pass into the ciliated cubical cells which line the remainder of the efferent duct. Van Bemmelen suggests that the flagellate portion arising from the kidney-duct opens into the pericardium; and that the ciliated duct, which certainly opens to the exterior, arises from the kidney-body and not from the kidney-duct, as Sedgwick had previously stated. Van Bemmelen concludes by saying:—"Although Dr. Haller and I have not examined the same species as Mr. Sedgwick, yet I am disposed to believe that the differences between his description and that of Mr. Sedgwick's and my own are not referable to variations of the species."

In reply to this criticism, Haller (13) states that he does not deny that the pericardial orifice may occur in some Chitons, and might naturally be expected to occur in *Chitonellus*, and in those Chitons which have a short row of gills, but that it does not occur in his species, though it may do so in Sedgwick's and Van Bemmelen's. He maintains the correctness of his former interpretation, and recalls the small blind diverticulum from the terminal kidney duct (*Nierenendgang*), and says: "I now believe that in this diverticulum is to be seen the rudiment of a former ancient opening (ciliated funnel, 'Wimpertrichter') into the pericardium in *Ch. siculus* and *Ch. fascicularis*, which opening, according to the statements of A. Sedgwick and Dr. Van Bemmelen, is said to be found in other forms" (I may add, though he does not refer to the fact, that in Haller's figure 36 (11) this diverticulum (*t*) is ciliated). Haller clearly suggests that a pericardial duct, where it exists, opens into the terminal portion of the kidney duct immediately before the

latter opens to the exterior—a position which is certainly at variance with the normal arrangement in molluscan or other excretory organs.

I have made at least two series of transverse sections through *Trachydermon ruber* (Linn.), from Norway,¹ and find that they corroborate Sedgwick's account in every essential point.

An examination of Plate X., figures 5–8, will render the subject quite clear. These are consecutive sections, one side of the animal only being drawn. I should add that the sections are a little oblique. Owing to the animals not being well preserved, I am unable to give histological details; but, in both the animals, the histological characters of the internal and external ducts are sufficiently well marked to prevent any mistake.

In figure 5 we have a section of the recurrent or pericardial duct of the kidney (*p. d.*) attached to the ventral wall of the pericardium; and external to this is the large thin-walled kidney-body (*k. b.*), the “bladder-like structure” of Sedgwick, with its glandular cæca on the lateral wall of the pericardial chamber; and opening into it is the cut end of a ciliated tube (*r. p. d.*). In the succeeding sections (Plate XI., figures 6, 7) this tube is seen to pass into the pericardial duct of the kidney, and is, in fact, a special recurved portion of that duct.

On the other hand, figures 7, 8, and the succeeding two sections, show the kidney-body passing outwardly through the muscular wall of the body, and curving over the lateral nerve-cord and below the branchial vein, eventually to open on the exterior mesial to the gill row.

The pericardial orifice of the kidney opens about the level of the outer communication of the auricles with the ventricle; and the external aperture is only a short distance posterior to it.

At present the case stands thus: Sedgwick says that there is a pericardial orifice in *Ch. discrepans* and *Ch. cancellatus*. Haller denies it in *Ch. siculus* (Gray) and *Ch. cajetanus*. Van Bemmelen has found it in *Ch. marmoreus* (Fabr.), *Ch. marginatus*, and *Chitonellus fasciatus*. I now describe it in *Ch. ruber* (Linn.). From indica-

¹ These specimens of *Ch. ruber* from the Natural History Museum were collected by P. Chr. Asbjørnsen of Norway, and were kindly placed at my disposal by my friend Mr. A. G. More, the Curator of the Museum.

tions in an imperfect series of *Ch. cinereus* (Linn.), I feel confident that it occurs in that form. And, lastly, I have seen it in *Ch. longicymba* (De Blainv.). The latter is one of the species collected by the "Challenger" Expedition. In my forthcoming Report on the anatomy of the group, which will be published by the "Challenger" Commission, I hope to be able to elucidate this and other points in the anatomy of this interesting group, by the examination of a larger range of forms than has as yet fallen to the lot of any naturalist; and till then I will not attempt any generalizations.

In the foregoing Paper I have simply spoken of the species referred to as belonging to the genus "Chiton." I now append a list of the genera, adopting the nomenclature which is in most general use:—

<i>Leptochiton cancellatus</i> ,	Sow.
,, <i>marginatus</i> ,	Penn.
<i>Trachydermon ruber</i> ,	Linn.
,, <i>albus</i> ,	Linn.
,, <i>cinereus</i> ,	Linn.
<i>Tonicella marmorea</i> ,	Fabr.
,, <i>submarmorea</i> ,	Midd.
<i>Ischnochiton longicymba</i> ,	de Blainv.
<i>Ischnoradsia trifida</i> ,	Carp.
<i>Lepidopleurus cajetanus</i> ,	Poli.
<i>Lepidoradsia australis</i> ,	Sow.
<i>Chiton siculus</i> ,	Gray.
<i>Acanthopleura picea</i> ,	Gmel.
<i>Mopalia wosnessenski</i> ,	Midd.
<i>Placiphorella improcata</i> ,	Carp.
<i>Acanthochiton discrepans</i> ,	Brown.
,, <i>fascicularis</i> ,	Poli.
<i>Cryptochiton stelleri</i> ,	Midd.
<i>Chitonellus larvæformis</i> ,	de Blainv. (= <i>Chl. fasciatus</i> , Quoy et Gaim).

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EXPLANATION OF PLATES X. AND XI.

All the figures are from spirit-preserved specimens of *Chiton* (*Trachydermon*) *ruber* (Linn.), and are drawn to the same scale, *i. e.* about 28 diameters.

Ao., aorta. *au.*, auricle. *b. a.*, branchial artery. *br.*, gill. *b. v.*, branchial vein. *c.*, commissure of pedal nerve cord. *e. d.*, external duct of the body of the kidney. *ft.*, foot. *gl.*, fenestral gland. *int.*, intestine. *k. b.*, body of the kidney. *l. f.*, longitudinal fold of the mantle. *l. n. c.*, lateral nerve cord. *m.*, mantle. *od.*, oviduct. *opng.*, opening of the kidney into the pericardium. *ov.*, ovary. *o. ov.*, external orifice of oviduct. *pc.*, pericardium. *p. d.*, pericardial or recurrent duct of the kidney. *p. n. c.*, pedal nerve cord. *p. v.*, pedal blood-vessel. *pv. c.*, perivisceral cavity. *r.*, rectum. *r. p. d.*, recurved portion of pericardial duct of the kidney. *v.*, cavity caused by the decalcification of an anterior sutural lamina of the succeeding valve.

Plate X., Fig. 1.—Transverse section of body in region of the oviduct, giving a longitudinal section of the latter (combined from three consecutive sections).

Figs. 2, 3, and 4.—Transverse sections of another specimen at the posterior end of the body, in the region of the "fenestral gland," of which 2 is the most anterior, and 3 the most posterior. Notice the complexity of the infoldings of the gland; the scattered groups of polygons are transverse sections of other portions of the gland. In Fig. 2 the auricles (*au*) are seen; in Fig. 3 they fuse together; and in Fig. 4 their posterior wall is just seen. The pedal nerve cords are seen to gradually dwindle away posteriorly.

Plate XI., Figs. 5, 6, 7.—Portion of transverse sections in region of the kidney-ducts of same specimen as Fig. 1, showing the opening of the pericardial duct into the pericardium, and the external duct of the kidney-body.

Fig. 8.—Diagram to show the relations of the urinary ducts.

XXX.—ON THE ORIGIN OF FRESHWATER FAUNAS: A STUDY
IN EVOLUTION. BY W. J. SOLLAS, M.A., D.Sc., F.G.S.,
Professor of Geology and Mineralogy in the University of
Dublin. (Abstract.)

[Read, May 19, 1884.]

THE poverty of freshwater faunas as compared with marine is commonly attributed to a supposed inadaptability on the part of marine organisms to existence in fresh water. That this explanation is altogether inadequate is shown by the existence of freshwater jelly-fish such as *Limnocodium*, and still more directly by the experiments of Beudant, who succeeded in accustoming several kinds of marine mollusca to a freshwater habitat. The view of Von Martens is, that the severity of a freshwater climate is prohibitive of the existence of most marine forms in rivers, and especially in the rivers of temperate regions. This cause, though no doubt efficient, is not altogether sufficient, and a more thoroughgoing explanation is necessary. This is chiefly to be found in a study of the means by which a wide distribution of marine animals is secured. In the case of stationary forms this is accomplished by means of free-swimming embryos, and as these are transported by currents, they can never pass from the sea into rivers, in which the current is always directed seawards. Nor, probably, could an attached form once introduced into a river permanently establish itself so long as its propagation took place exclusively through free-swimming larvæ, for these would gradually be borne out to sea. Hence, freshwater animals should not, as a rule, pass through a free larval stage of existence, nor as a matter of fact do they. In the Hydra, freshwater Sponges, and Polyzoa, the young usually emerge from a horny cyst in the complete state. In the Unionidæ, the glochidium stage provides for a distribution, in which a journey invariably seawards is not involved.

Paludina is viviparous, and as in the case of other freshwater molluscs, the young do not enter upon a free existence till they are essentially similar in their mode of movement to their parents.

The suppression of a free-swimming larval stage is not only met with in freshwater animals, but is frequent with many marine invertebrates. This is connected with the fact that the larval stage is in a position of disadvantage as compared with the adult. On the doctrine of evolution, the more complex structure of the adult animal implies this. Hence there is an advantage to the organism if the larval stage can be passed over, withdrawn as far as possible from the chances of the environment, in a state of seclusion. From this various other modifications follow; development in seclusion necessarily involves a supply of easily accessible food, hence the appearance of yelk and other kinds of nourishment furnished by the parent to the imprisoned embryo. Again, the energy of the larva being economized in various directions (it is spared the drudgery of working for its own existence, and is supplied with nutriment in a form that makes the least demands on its digestive powers, a larger balance remains available for metamorphic changes. Thus arise the phenomena of accelerated and abbreviated development. Further, the shortening of the larval life probably leads to the lengthening of the adult life, and shifts the chances of variation and selection forwards into the adult stage. Thus animals which hatch out in a complete state will most probably suffer modifications of that state, and not of previous ones, except very indirectly. Here we discover a direct tendency towards a mode of development which explains the "arborescent" character of our most natural methods of classification, *i.e.* the tendency of the tree of life is now to produce leaves rather than new branches. In the case of freshwater fauna very direct reasons have existed for the suppression of the free larval stage. These are to be found in the severity of the climate and the dangerous direction of the river current. In connexion with the suppression of the larval stage may be noticed the richness in species and the poverty in genera of the freshwater mollusca.

In discussing the origin of freshwater fauna, there are three hypotheses from which we have to select: 1, that marine forms have migrated directly into rivers; 2, that they have first become adapted to existence in marshes, and subsequently have entered rivers; and 3, that marine areas have been converted into freshwater ones. The last holds most frequently, especially in the case of attached non-locomotor forms. Hence the origin of freshwater

animals (invertebrates) is connected with the great movements which have affected the earth's crust. The earliest well-known lacustrine areas are those of the Old Red Sandstone, the direct descendants of the preceding Silurian seas. In the deposits of one of these lakes we meet with the earliest known freshwater mollusc, *Anodonta jukesii* (Forbes). Probably, considering the remoteness of the alliance of *Lymnæa* to existing marine genera, it also, and, perhaps, *Valvata* with it, originated at the same time as *Anodonta*.

The lakes of the Permo-Triassic period, the residues of carboniferous seas, produced considerable additions to the freshwater fauna of the globe. The *Neritidæ* and *Cerithiadæ* are probably post-Palæozoic families, and as the *Neritidæ* and *Melaniidæ* are so closely connected with them, they may be regarded as collateral, or more probably direct descendants, and thus may have originated in Triassic lakes, but not earlier. Other genera probably arose at the same time; the occurrence in Cretaceous deposits of *Unio*, *Physa*, *Valvata*, and *Lymnæa* in the Nearctic, Palæarctic, and Oriental regions, suggest a high antiquity for these genera; but they may have existed, as we have suggested, in Palæozoic times.

The lakes of the Tertiary period furnished probably further contributions to our freshwater fauna, such as *Lithoglyphus* and *Dreissena*. Thus, existing freshwater genera are probably descended from marine forms which became metamorphosed in the waters of the Devonian, Triassic, and Tertiary lakes. In the lakes of Central Africa the tertiary freshwater fauna still survives; nearly all of the genera from Lake Tanganyka, described by Edgar Smith, being referable to genera already in existence in Mesozoic and Tertiary times. The lakes of the Northern Hemisphere received, on subsiding beneath the glacial sea, such arctic forms as *Mysis relicta* and *Pontoporeia affinis*, but most of their existing inhabitants have re-entered them, since their emergence from the sea, from their tributary rivers, or the rivers of adjacent regions.

XXXI.—ON THE ACTION OF WAVES ON SEA-BEACHES AND
SEA-BOTTOMS. BY ARTHUR ROOPE HUNT, M.A.,
F.G.S.

[Read, March 17, 1884.]

THE action of waves on sea-beaches and sea-bottoms has been much discussed during the last fifty years, but apparently without much practical result, as there is scarcely an important point connected with the subject that is accepted without dispute, whilst not only the opinions, but even the recorded observations, of skilled observers are often, to all appearance, in hopeless conflict,

Current scientific opinion on this question may be conveniently gathered from three valuable Papers¹ published in the *Proceedings of the Institution of Civil Engineers*, viz. :—

* “On the Alluvial Formations and Local Changes of the South Coast of England,” by John Baldry Redman, M. Inst. C. E.—*Proc. Inst. C. E.*, vol. xi.

* “Description of the Chesil Bank, &c.,” by John Coode, M. Inst. C. E.—*Proc. Inst. C. E.*, vol. xii.

* “On the Origin of the Chesil Bank, &c.,” by Joseph Prestwich, M. A., F. R. S.—*Proc. Inst. C. E.*, vol. xl.

These Papers, together with the discussions that followed them, furnish the student with the opinions of upwards of thirty men of science specially interested in the subject of wave action, either as engineers, geologists, or physicists.

More recently Mr. G. H. Kinahan has continued the discussion of the subject generally in the following Papers, viz. :—

“Drifting Power of Tidal Currents *versus* that of Wind-waves.”—*Proc. Roy. Irish Acad.*, s.s. vol. ii., Science, p. 443, 1875.

* “Lagoons on the S.-E. Coast of Ireland.”—*Proc. Inst. C. E.*, vol. xlv.

“On the Chesil Beach, &c.”—*Quarterly Journal Geological Society*, 1877.

* “The travelling of Sea Beaches.—” *Proc. Inst. C. E.*, vol. lviii.

¹ The Papers marked thus [*] are referred to according to their pagination as reprints, the volumes of the Proceedings of the various Societies in which they are published not being within my reach.

My object in the present Paper is twofold, being firstly, to set forward as plainly as possible the conflict of authority that exists on the action of sea waves, with a view to induce competent observers to investigate a subject which is of such importance to both engineers and geologists; and, secondly, to attempt, by means of my own experiments and observations, to reconcile certain facts recorded by observers of unquestioned veracity, which facts seem at first sight to be quite irreconcilable, and have indeed been regarded as such.

Nor can non-mathematical observers of wave-action place implicit reliance on the results obtained by those who have studied the subject from a theoretical point of view, as here also some of the authorities of greatest repute fail to agree.

The Reports of Mr. Scott-Russell, published under the auspices of the British Association, and "A Treatise on Tides and Waves," by Sir George Airy, in the *Encyclopædia Metropolitana*, are authorities much relied on at the present time. Referring to the former, Mr. Kinahan remarks:—

"It might have been supposed that the exhaustive report on Waves by J. Scott-Russell, F. R. S., &c., should have decided the relative merits of the tidal currents and wind-waves in regard to their drifting powers" (*Proc. R. I. Acad.*, s.s. vol. ii., p. 443); whilst Lord Rayleigh has referred to the latter work as "still probably the best authority on the subject" ("On Waves," *Phil. Mag.*, s. 5, vol. i., 1876, p. 262).

Unfortunately the writers of these authoritative works were not agreed as to certain important points. Sir George Airy warned his readers against a too ready acceptance of Mr. Russell's first Report on Waves, in the following terms:—"We shall repeat our opinion of the great value of the experiments which we have abstracted, but we must warn the reader against attaching any importance to the theoretical expressions which are mingled with them in the original account" ("Tides and Waves," paragraph 415). To this Mr. Russell subsequently replied:—"... there is an irresistible body of evidence in favour of the conclusion that Mr. Airy's formulæ do not present anything like even a plausible representation of the velocity of the wave of the first order, and that the formula I have adopted does as accurately represent them as the inevitable imperfections of all observations will admit. It

is deeply to be deplored that the methods of investigation employed with so much knowledge, and applied with so much tact and dexterity, should not have led him to a better result" (*Trans. Brit. Assoc.*, 1844, p. 337).

Thus, on the threshold of his inquiry into the action of waves on sea-beaches, the student is confronted with the fact that two authorities of great repute on the theory of waves are at variance as to the character of that particular form of wave, viz. the wave of the first order, to the exceptional powers of which the most striking wave phenomena of the coast are commonly attributed.

The following extracts from the published opinions of authors of eminence in their respective branches of science will suffice to indicate the divergence of opinion that exists with regard to the following fundamental questions as to the action of waves on beaches, viz. :—

The motion of shingle under water, and its cause, variously attributed to wind-waves, ground swells, tidal waves, tidal currents, and other sub-marine currents?

The horizontal motion of shingle on beaches; whether the large material outstrip the small, or *vice versâ*?

The vertical motion of shingle on beaches; whether small or large attain the greatest altitude?

The degrading and accumulating action of waves; whether large waves or small exert the one action or the other?

As frequent reference will be made to the above-mentioned Papers of Messrs. Coode, Prestwich, and Redman, and to the discussions that followed them, it will be convenient to quote them under the letters C., P., and R., respectively.

[OPINIONS, &c.]

OPINIONS AS TO THE MOTION OF SHINGLE UNDER WATER.

Sir E. BELCHER.

"... the waves during heavy gales exercised power at very great depths; he had seen evidence of it in water fourteen fathoms deep. He thought the tide current did not affect depths of more than 12 or 14 feet."—R. 49.

Professor AIRY.

"Although a swell might roll up the centre of the English Channel, yet there was a tendency in all such places for the direction of the waves to change gradually, as towards the general line of shore, and to roll pebbles that way. He quite agreed in the opinion that very little was ascribable to the action of the tide."—C. 38.

Mr. SCOTT RUSSELL.

"It did not appear from the Admiralty charts, that near these shingle beaches there were any tidal currents of sufficient velocity to move stones of the bulk of those forming the banks; therefore he was warranted in attributing their formation, chiefly, if not entirely, to the action of wind-waves in conjunction with the local causes he had endeavoured to point out."—R. 63.

Mr. R. A. C. AUSTEN.

"This process, by which masses of solid materials can be planed off parallel with the sea level, is due to the action of wind or surface-waves, inasmuch as in calm weather, when I have had opportunities of passing over some of these platforms, I have felt convinced that the only other agent, namely the tidal streams,

Mr. J. M. RENDEL.

"... his own opinion was, that shingle could scarcely be moved by the heaviest waves, at greater depths than three fathoms."—R. 64.

Mr. JOSEPH GIBBS.

"... the movement of the beach in question was not so much due to the ordinary flow, as to what might be termed submarine currents, which had the power of carrying pebbles along the shore at great depths until the waves cast them up as shingle."—C. 35.

Mr. G. H. KINAHAN.

"... at Chesil the driftage is due to the flow-tide current, augmented by waves caused by the prevailing winds, while at Cahore the driftage is solely due to the flow-tide currents, its effect being modified by adverse wind-waves; ... the sorting of the pebbles on Chesil beach is probably principally caused by the progressive increase in the velocity of the tidal current as it approaches the nodal or hinge-line of the tide in the English Channel."—Q. J. G. S., 1877, p. 41.

Mr. J. THORNHILL HARRISON.

"No wind-waves acting upon a beach would ever have excavated the bed of the bay to its present depth, and some other forces must therefore have been in operation. Among those forces, he believed, were the tidal action, which was very considerable in the bay, and the groundswells, which came into it with enormous

had not sufficient velocity to exercise any mechanical power whatever.”—Q.J.G.S. vol. vi. p. 73.

“The two actions, first, that of wind-waves when they break in shallow water; and secondly, that of the tidal stream, are alone engaged in fashioning and arranging the materials of the sea-bed. . . . In every sea the power of abrasion is confined to a marginal zone, and that of dispersion, though with a wider range, extends only to the minuter particles of matter.”—*Ibid.* p. 75.

MR. JOHN MURRAY.

“On the east coast, the shipping which frequented the coal ports, cast out at sea, particularly in fine weather, great quantities of ballast in water 10 to 20 fathoms deep. The greater part of this ballast was composed of sand and pebbles dredged from the Thames, with chalk and other matter foreign to the East Coast. After storms, the shore between the Tyne and Hartlepool was strewed with these pebbles, which could only have been brought there by the action of the waves at the depths stated.”—C. 34.

MR. JOSHUA WILSON.

“... waves possessed sufficient power to move shingle at considerable depths: inasmuch as though, at Sunderland, no vessels were permitted to throw ballast overboard at a less depth than 5 fathoms, yet great quantities of flint pebbles were found on the beach, which could only have been derived from that source, as they were not met with ‘*in situ*’ in any cliffs within the range of the seas bearing on Sunderland.”—R. 55.

violence . . . The Astronomer Royal’s¹ view, that the materials which formed the bank were piled up by the sea, after having been torn up by the violence of the surf from the bottom, coincided very nearly with his own.”—P. 36 and 38.

MR. J. N. DOUGLASS.

“... the travel of the shingle was, he thought, chiefly due to the effects of the ocean-wave or ground-swell He quite agreed with the opinion expressed by Mr. J. T. Harrison, that the beach (Chesil) had been largely supplied with material from the bottom of the bay; indeed, he considered it quite possible that a portion of the supply had been transported from positions westward of the Start.—P. 45 and 46.

PROFESSOR PRESTWICH

thought that the shingle was driven on to the Chesil Bank “by the storms to which this coast is exposed acting probably conjointly with the great tidal wave. This wave, passing from the ocean into the shallower waters of the channel, becomes a wave of translation, which under certain conditions, such as a rapid decrease of depth, or the narrowing of its channel, possesses a greater or less propelling and eroding power.”—P. 18.

MR. KINAHAN.

“Lyme Bay . . . is open, and the Chesil Beach is exposed to the full force, not only of the tidal current, but also of the most prevailing and effective winds. The current also is progressively increasing in velocity as it goes eastward, and therefore carries large fragments with it to be driven on shore . . .”—Q. J. G. S., 1877, p. 40.

¹ Sir G. Airy.

OPINIONS AS TO THE RELATIVE MOTION OF LARGE AND SMALL SHINGLE
ALONG SHORE.

Professor (now Sir GEORGE) AIRY.

" . . . the progression in smallness of the pebbles pointed to the direction from which the current or fluctuation must have transported them . . . ; they must have been transported from the end of the bank, where they were large, towards the end where they were small."—P. 32.

Admiral SPRATT.

" . . . On one occasion, on the coast of Egypt, he put overboard five bags of clinkers, weighing from 3 lbs., 4 lbs., and 5 lbs., to a few ounces; and on visiting the spot a fortnight afterwards to examine the effect of wave-action, he found at 450 yards to leeward the largest pieces of clinker nearest the point of starting, one weighing $3\frac{1}{2}$ lbs. and the other 2 lbs.; at 700 yards and 800 yards they weighed less than 1 lb., and at 1500 or 1600 yards, from $\frac{1}{2}$ to $\frac{1}{4}$ oz. only. Thus the heaviest and largest pieces did not travel the farthest, but the contrary.—P. 31.

Mr. A. GEIKIE.

" A prevalent wind, by creating a current in a given direction, or a strong tidal current setting along a coast-line, will cause the shingle to travel coastwise, the stones getting more and more rounded and reduced in size as they recede from their sources. The Chesil Bank, which runs as a natural breakwater 16 miles long connecting the Isle of Portland with the mainland of Dorsetshire, consists of rounded shingle which is constantly being driven westwards."—*Text-Book of Geology*, p. 435.

Mr. (now Sir JOHN) COODE.

" . . . the cause of the large shingle being found, at what is called 'to leeward' upon any beach, is due to the fact of the large pebbles moving more readily than the small, . . . "—C. 25.

Mr. REDMAN.

" Undoubtedly the largest shingle travelled to leeward, . . . "—P. 44.

Mr. T. MELLARD READE.

" It was not, as Sir John Coode supposed, that the large stones were the more easily moved, for the reverse could be readily proved, . . . the large stones, in fact, travelled up a lesser gradient, and consequently to a greater distance."—P. 24.

Sir CHARLES LYELL

" . . . admitted the apparent paradox of the largest pebbles at the Chesil Bank being found to leeward; or farthest from the source whence they were derived; as he took it for granted that they did come from the westward. . . . "—R. 47.

" . . . throughout the Chesil Bank the pebbles increase gradually in size as we proceed south-eastward, or as we go farther from the quarter which supplied them."—Lyell's *Principles Geol.* vol. i. p. 539, 11th ed.

Mr. R. A. C. AUSTEN.

" Along our own southern coasts the movement of shingle is from west to east, and on the opposite coast of France it is the same. . . . On the Chesil beach may be collected pebbles of limestone, greenstone, trap, and old red sandstone, derived from the older rocks of South Devon."—Q.J.G.S. vol. vi. pp. 72, 73.

OPINIONS AS TO THE ACCUMULATIVE AND DESTRUCTIVE ACTION OF WAVES
ON BEACH-SHINGLE.

Mr. COODE.

"It is known that shingle accumulates upon any beach with off-shore winds, whilst it is carried off, or scoured away, during on-shore winds, and more especially by the ground-swell which follows."—C. 23.

Mr. PALMER.

"I watched for an opportunity of witnessing that rate of succession which exhibited the destructive and accumulative actions in their smallest degrees; and I observed that when ten breakers arrived in one minute, the destructive action was but just evinced; and that when only eight breakers arrived in the same period, the pebbles began to accumulate; which facts harmonized with my observations made at Sandgate and Folkestone, viz. that the difference between the two actions was determined by the rapidity in succession of the waves upon the shore."—*Trans. R. S.*, 1834, p. 571.

Mr. KINAHAN.

"The ordinary wind-waves assist the flow-tide currents when they are going in the same, or nearly the same, direction with those currents. If they strike the beach at a right angle, or nearly so, they pile it up, forming 'fulls' and 'storm-beaches' . . ."—*Travelling of Sea Beaches* (*loc. cit.*), p. 3.

Mr. Kinahan, writing of the east coast of Ireland between Carnsore and Dalkey, says:—

"W. and S.-W. winds generate ground-swells, which usually cut out the beaches."—*Ibid.* (*loc. cit.*), p. 4.

(These winds are off-shore.)

"Ground swells with E. winds sometimes seem to assist in filling in the beaches, but with N.-E. winds they cut out."—*Ibid.* (*loc. cit.*), p. 5.

(These winds are on-shore.)

Mr. COODE.

"The views here expressed" (Mr. Palmer's) "are opposed to the conclusions arrived at from the Author's observations on the Chesil Bank and elsewhere. The rule, as far as one can be formed from the number of waves in a given time, appears to be, that seven, or any less number of waves per minute, indicate the destructive action, and nine, or any greater number, the accumulative action; but no very precise rule can be formed upon this basis."—C. 23.

Although no one would venture to question the *bona fides* of an observation recorded by Mr. Palmer, Sir John Coode, or Mr. Kinahan, yet, in the above extracts on the subject of accumulation and removal of beach material, we find the following facts vouched for, viz. :—

(1). “Shingle accumulates with off-shore winds.”

(2). “W. and S.-W. winds” (between Carnsore and Dalkey where they are off-shore) “generate ground-swells, which usually cut out the beaches.”

(3). “Shingle is carried off . . . more especially by the ground-swell which follows” (on-shore winds).

(4). “Ground-swells with E. winds” (these being on-shore at the locality referred to) “sometimes seem to assist in filling in the beaches.”

(5). “When ten breakers arrived in one minute, the destructive action was but just evinced; when only eight breakers arrived in the same period, the pebbles began to accumulate.”

(6). “. . . Seven, or any less number of waves per minute indicate the destructive action, and nine, or any greater number, the accumulative action.”

In the presence of statements so contradictory as the above to all appearances are, there is some risk of an observer relying on his own observations to the exclusion of those previously recorded. The conflict of observation between Mr. Palmer and Sir John Coode (quoted above) seems a case in point. Sir John Coode, finding his own observations apparently irreconcilable with those of Mr. Palmer, seems driven to the expedient of relegating Mr. Palmer's observations to the rank of “views,” as opposed to the “conclusions” arrived at from his own. Taking into consideration the eminence of the two observers, I cannot but think that no such mode of explanation is admissible. In both cases we have to deal, not with “views,” but with well-attested facts.

The following observations and experiment, made in the autumn of 1882, with the object of solving, if possible, some of the problems suggested by the above extracts, may be worth recording, if only

to show how easily students of wave-action may be misled by a misinterpretation of isolated observations :—

(1). *Sept.* 3, 1883.—Cove under St. Lawrence, Isle of Wight. Heavy sea. Waves, six per minute. Strand, small flint shingle, or coarse sand. Tide rising. The waves carried off every stone I placed on the beach, about mean water level, without apparently disturbing the coarse sand. One of the stones was nearly spherical, and some ten inches in diameter.

(2). *Sept.* 27, 1882.—Sands under Torbay Hotel, Torquay. Wind N.W., along shore. Small waves breaking on the sands from S.W. Low water. Whilst wading, observed the motions of light objects on the bottom. Could not see that they were driven forwards by the waves, but observed that they were driven to leeward by the wind, which seemed to drive the water before it, and to cause a current. When the tide was flowing quickly, light objects (*e. g.* an empty echinus shell) were driven before it shorewards, rather fast; but here it was clearly the tidal current that was the motive power. Where the surf was breaking I could not see the bottom, though only a few inches below the surface. I came to the conclusion that the sand was stirred up by the plunging waves, and that what became of it then must depend upon currents.

(3). *Sept.* 28, 1882.—Sands (flat) at Livermead. Tide flowing. Determined to ascertain whether the little “translation” waves running along the shallow water, with their forward slopes apparently high above the level of the water in front, had any power to drive objects before them. A piece of large leathery seaweed (*laminaria*) showed a decided tendency to go shorewards; but this arose from the fact that it was carried along bodily by the shoreward current, to whose impulse it yielded at once; whereas, having anchored itself when the current slackened, it did not start seawards till the gradually increasing outward current had attained considerable velocity, and spent much of its power. A piece of heavy water-soaked stick was carried away seawards much faster than the piece of *laminaria* was carried shorewards. The stick was too heavy for the incoming waves to lift, and had to be rolled

both ways; whereas the piece of *laminaria*, though rolled backwards, was light enough to be lifted forwards.

(4). The foregoing observations having been made, the tide, having in the meantime covered the flat sands, had reached a sloping beach. Thrusting a razor shell (*solen*) into the sand of this beach for a mark, I watched the action of the waves on a stone lying on the slope. It gradually worked its way up the rather steep incline, notwithstanding the fact already referred to, that the water-soaked stick had travelled seawards down one whose gradient was much less.

EXPERIMENT.—*Sept.* 30, 1882.—In front of a small sloping sand-beach, in my experimental tank, I placed a large slate, carefully levelled with a spirit-level. The slate was then covered with water to the depth of about one inch, so that the waves produced by my wave-generator might break heavily on it. I found that marbles placed on the slate evinced a decided tendency to travel outwards against the waves, but that fragments of crushed granite were washed shorewards. Once only was a piece of granite washed off the slate.

(5). *Oct.* 3, 1882.—Walked from south end of Goodrington sands (Torbay) to north-east end of Hollowcombe sands. Tide ebbing. Came to the conclusion that when the waves do not break, the combined action of the inward and outward currents washed objects on the bottom outwards, but that breakers carried forwards whatever they could lift.

(6). *Oct.* 4, 1882.—Beach east of raised beach at Hope's Nose. Tide (neaps) ebbing. Waves inclined to roll stones up the sand-slope. Sand softish and coarse; seemed to offer much resistance to descent of the stones. One rounded flint, the size of an egg, was driven up several times.

The breakers were most decided in their upward action; but even the wash backwards and forwards showed no tendency towards downward propulsion. (N.B.—This conflicts with Observation (5)).

The above six observations way be tabulated as follow:—

Number of Observation.	State of Tide.	Motion of beach-stones, or other movable objects.
1	Flowing . .	Seaward.
2	Low Water .	Neutral.
3	Flowing . .	{ Piece of <i>laminaria</i> —shoreward. Water-soaked stick—seaward.
4	Flowing . .	Shoreward.
5	Ebbing . . .	{ Breakers—shoreward. Wash—seaward.
6	Ebbing . . .	{ Breakers—shoreward. Wash—neutral.

Hitherto I had failed in my attempt to reconcile the conflicting observations of the authorities referred to in the preceding pages. My own observations had been as contradictory, and seemingly as irreconcilable, as theirs. The only fact clearly made out seemed to be, that the forces acting on marine shingle, or on other objects under water, were very evenly balanced, and that a slight change either in their mode of application or in the character of the shingle or other objects on which they acted might, in any particular case, completely reverse the effect of their action.

Having in the preceding pages shown the uncertainty which prevails at present as to the action of waves on sea-beaches, I will now proceed with my attempt to reconcile some of the observations recorded above, my own included, which observations often seem as inconsistent and contradictory as they are well attested.

The first step towards this result will be an endeavour to disprove the assumption that is commonly made, that under certain circumstances an ordinary oscillating marine wave can convert itself into a wave of translation; or, as Mr. Russell puts it, that “the wave of the second order may disappear, and a wave of the first order take its place.” (*Trans. Brit. Assoc.*, 1844, p. 372.) Mr. Russell defines the two orders of waves as follows:—“The *wave of translation* is the wave of the FIRST ORDER, and consists in a motion of translation of the whole mass of fluid from one place to another, in which it finally reposes. . . .” (*Ibid.* p. 317.) “This

wave-form has its surface wholly raised above the level of repose of the fluid. This is what I mean to express by calling this wave *wholly positive*. . . . The wave-proper of the first order is wholly positive." (*Ibid.* 340.)

"The wave of the SECOND ORDER is partly positive and partly negative, *each height having a companion hollow*, and this is the commonest order of visible water-wave, being similar to the usual *wind-waves*, in which the surface of the water visibly *oscillates* above and below the level of repose." (*Ibid.* 317.)

Mr. Russell distinctly asserts that ordinary sea-waves of the second order become, on certain occasions, entirely transformed into waves of his first order. He writes:—"After a wave has first been made to break on the shore, it does not cease to travel, but if the slope be gentle, the beach shallow and very extended (as it sometimes is for a mile inwards from the breaking point, if the waves be large), the whole inner portion of the beach is covered with positive waves of the first order, from among which all waves of the second order have disappeared. This accounts for the phenomenon of breakers transporting shingle and wreck and other substances shorewards after a certain point; at a great distance from shore, or where the shores are deep and abrupt, the wave is of the second order, and a body floating near the surface is alternately carried forward and backward by the waves, neither is the water affected to a great depth; whereas nearer the shore, the whole action of the wave is inwards,¹ and the force extends to the bottom of the water, and stirs the shingle shorewards; hence the abruptness also of the shingle and sand near the margin of the shore where the breakers generally run." (*Ibid.* p. 373.)

The results arrived at by Mr. Russell as to the nature of his wave of the first order were obtained by means of a series of elaborate experiments; but the above conclusions as to the conversion of waves of the second order into those of the first order seem to have been based on an insufficient number of general observations that were not brought to the test of experiment.

¹ According to Mr. Russell the wave may assume this character before it breaks:—"He must undoubtedly attribute the greatest moving power to the greatest depth of water, because the largest and most powerful wave would thus be created, and before they broke they would exercise the greatest amount of mechanical power to lift and convey the shingle." (R. 53.)

The assertion that is made is sufficiently startling, as it is in effect that a wave of oscillation that propagates itself by means of a pendulum-like vibration about the level of repose of the water can be raised entirely above that level, and there sustained, without the intervention of any force outside itself.

Mr Russell, in his first report to the British Association, describes an experiment made with marine waves, in the following passage:—“The phenomena of waves breaking on the shore were observed principally on a very fine smooth beach of sand, having a slope towards the sea of 1 in 50; so perfectly plane and level was it at the time when the observations were made, that a single wave a mile in breadth might be observed advancing to the shore, so perfectly parallel to the edge of the water that the whole wave rose, became cusped, and broke at the same instant; a line of graduated rods was fixed in the water at different depths from 6 inches to 6 feet in length, and it was observed that every wave broke exactly when its height above *the antecedent hollow* was equal to the depth of the water.”—(*Trans. Brit. Assoc.*, 1837, p. 450.) The words I have italicised, if taken in their literal sense, would be sufficient to settle the question at issue, for waves with antecedent hollows, by Mr. Russell’s own definition, are not waves of the first order, as the latter have their surfaces “wholly raised above the level of repose of the fluid.” Sir George Airy, commenting on this passage (*Tides and Waves*, 403), remarks that Mr. Russell does not state “whether this depth was measured from the mean level of the surface, or from the bottom of the hollow,” and thus clearly assumes that the “bottom of the hollow” and Mr. Russell’s “antecedent hollow” are not equivalent to the level of repose. Mr. Russell’s meaning is, however, open to some doubt, as on a subsequent occasion he defined “the limit of height of a wave of the first order” as “a height above the bottom of the channel equal to double the depth of the water in repose.”—(*Trans. Brit. Assoc.*, 1844, p. 352.)¹

There can, however, be little doubt that waves derived from waves of oscillation under the circumstances described by Mr.

¹ The question is whether, in the passage referred to, Mr. Russell uses the words “antecedent hollow” in their ordinary sense as descriptive of a depression extending below the level of repose of the water, or as descriptive of the depression between two waves of his first order, which depression, according to his own definition, must not (as part of a wave of the first order) extend below the said level of repose.

Russell are accompanied by antecedent hollows, though the depression may be small, and very extended, in proportion to the height of the wave. The fact can be easily proved in the case of artificial oscillating waves made to roll over water of gradually diminishing depth. If under these circumstances a wire be stretched across the water at the level of repose, it will be found that on the approach of a wave the water will sink away, and leave the wire suspended in mid-air, thus showing that each wave is preceded by a depression.

If oscillating waves, on approaching the shore, were transformed into waves of translation, raised entirely above the level of repose of the water, it would naturally follow that such waves would plunge on the shore landwards of the margin of repose for the time being.

This point, as affecting the erosion of the land by sea-waves, is of some importance to geologists. Professor J. D. Dana seems to refer to it in the following passage: "Since a wave is a body of water rising above the general surface, and when thus elevated makes its plunge on the shore, it follows that the upper line of wearing action may be considerably above *high-tide* level. Again, the lower limit of erosion is above *low-tide* level; . . . there is therefore, a level of greatest wear, . . . and another of no wear, which is just above low tide."—(*Man. of Geol.*, 3rd ed., p. 676.)

Now, this statement, though strictly in accordance with Mr. Russell's theory, has, so far as I can ascertain, no foundation in fact. An attentive study of heavy waves breaking on a beach will satisfy the observer that all waves derived from oscillating waves break far below, or seawards of, the margin of repose of the water. As it is sometimes difficult on the sea-shore to detect the line of mean level for the time being, it will, perhaps, be better in the present inquiry to let observation be preceded by experiment.

On the 5th October, 1882, I banked up the sand at one end of my experimental tank, and caused waves to attack this artificial cliff for about three quarter of an hour. My object was to ascertain the general action of waves in tearing down and distributing beach material, and I find no special entry in my note-book as to the relation of the line of plunging with the water margin; but a series of careful measurements recorded at the time supplies the information required.

At the close of the experiment, the breadth of the strand from

cliff to water margin, and the distance from water margin to the plunging line, were measured at five equi-distant points, viz. at the two sides of the tank, at the centre, and at the two intermediate points, with the following result, viz. :—

—	Inches.					
						verage
Breadth of strand from cliff to margin of water	$3\frac{1}{2}$	$3\frac{3}{4}$	$3\frac{3}{4}$	$3\frac{1}{2}$	$3\frac{3}{4}$	$3\frac{1.8}{2.0}$
Margin of water to plunging line of waves	8	6	5	7	$8\frac{1}{2}$	$6\frac{1.8}{2.0}$

In this experiment the waves were furnished with a cliff of soft sand to work on, and formed their own beach and along-shore bottom, which, as in nature, was a comparatively flat one.

Subsequently I made some special experiments, to ascertain the point of plunging relative to the point of furthest reach of waves breaking on a beach. A large roofing slate, with parallel lines ruled across it one inch apart, was employed.

This slate being laid on the artificial beach, with one of the cross lines coincident with the margin of the water, enabled the observer to see at a glance how many inches “seaward” of the margin of repose the waves plunged, and how many inches shoreward of the same margin they reached. One particular line was always used for marking the water-level, and was distinguished by the letters W. L. From this line the remainder were numbered 1, 2, 3 in each direction. In an experiment made in February, 1883, the highest reach of the waves, as defined by a row of light chips washed on to the slate, was just under three inches above the water-line, whilst the line of plunging (rapidly scratched on the slate during the progress of the experiment) was over eight inches below the water line. The slope of the slate was not measured.

On a subsequent occasion the experiment was repeated, with the slate inclined at an angle of 6 degrees, and with waves at the rate of 98 per minute. In this case the waves plunged about eight inches short of the margin of repose, whilst their furthest reach was about five inches beyond it. In both these experiments the line of

plunge of the waves was more remote from the water margin on the one side than the line of furthest reach was on the other.

With the eye trained by observing the plunge of waves, where the margin of repose is known, it is not difficult to make a fair estimate of that margin when heavy waves are rolling on to a sea-beach, and to assure oneself that in no case do heavy waves plunge anywhere near the margin of repose of the water for the time being—I say advisedly, heavy waves, for the action of short wind-waves is at times completely masked and rendered unintelligible by the presence of long, low swells, whose concurrent action may occasionally pass unobserved.

In investigating the action of an oscillating wave approaching the shore it will be well to select an ordinary swell as being no longer under the influence of the wind or other force that may have brought it into existence.

In the case of such a wave, authorities seem agreed that the motion is one of oscillation solely, and that there is no translation of the water in the direction of propagation of the wave. In a passage already quoted, Mr. Russell, referring to a wave of this kind, says that “a body floating near the surface is alternately carried forward and backward by the waves. . . .” Lord Rayleigh, describing “periodic waves in deep water,” says that “the motion of each particle of the fluid is in a circle, which is described with uniform velocity.” (*Phil. Mag.*, s. 5, vol. i., 1876, p. 267.) The direction of this motion we may learn from Sir George Airy:—“The particle revolves uniformly in the circle of which we have spoken; moving forwards when at the highest part of the circle, and backwards when at the lowest part.” (*Tides and Waves*, 182.)

From the above descriptions of the motion of water under the influence of an oscillating wave it will be seen that the motion imparted to a floating body by such a wave will be more accurately described as backward and forward than as “forward and backward.” It is important to bear in mind that the primary motion of a floating object is towards the advancing wave, and therefore backwards as referred to the direction of advance of the wave; and that the wave draws its supplies entirely from the front, and not from the rear. The truth of this can be shown from the facts that the ridge of an oscillating wave is preceded by a depression, and that the motion of the wave is much more rapid than the motion of

the water composing it, even when the water at the highest part of the wave is travelling with its greatest velocity in the same direction as the wave.

Dr. Scoresby observed storm-waves in the Atlantic having a period of 16 seconds, and a speed of $32\frac{1}{2}$ miles per hour. For convenience sake we may consider the hypothetical case of a swell with a period of 15 seconds, a speed of 30 miles, and a height, from trough to crest, of 5 feet. In such a swell the circle described by a surface particle would have, in round numbers, a circumference of 15 feet, and the time taken in describing it would be 15 seconds. Thus the speed of the particle in a forward direction on the crest of the wave would be one foot per second, or 3600 feet per hour. But the speed of the wave itself is 30 miles, or 158,400 feet per hour; from which it follows that the speed of the wave is 44 times the speed of the water composing it, even when the latter, on the crest of the wave, is moving at its greatest velocity in the direction of the wave. Under these circumstances it is clearly impossible for such a wave to draw any of its supplies from the rear. The advancing wave depends entirely for its continued existence on the water in front of it, and on that only.

From the fact that a particle on the surface of the water moves "in a circle which is described with uniform velocity," it follows that each wave gives rise to two currents that are equal and opposite, the first flowing in a direction contrary to that of the advancing wave, the second flowing in the same direction as the wave. It will be convenient to refer to these currents as the primary and the secondary—terms descriptive of their order of sequence in point of time.

When a swell such as I have described reaches water sufficiently shallow for it (to use Mr. Russell's expression) "to feel the bottom," the primary current, extending as it then does, though with varying intensity, throughout the whole mass of the water from surface to bottom, flows over and in contact with the said bottom, in its passage to meet the advancing crest. The secondary current returning with, and following the crest, affects the bottom in a similar manner, though in an opposite direction. Thus the circular motion of a surface particle in deep water is resolved, so far as the bottom is concerned, into two equal and opposite horizontal currents. The action of these currents on a movable object on the bottom is, in

the first place, a motion of translation towards the advancing wave-crest, and in the second, a motion of translation in the same direction as that crest, the said object, if the bottom be level, being ultimately deposited at or about the same spot whence it set out. As the water shoals, and the depth in proportion to the size of the wave diminishes, the currents increase in amplitude and intensity ; but, so far as I can ascertain, remain equal and opposite, so long as the wave does not plunge. The action of these currents can be observed either from a boat at sea, when the water is clear and the waves of convenient dimensions ; or, in the case of artificial waves, in a suitable tank.

When a wave of oscillation is passing over and through a practically frictionless fluid, such as water, it may travel for hundreds of miles from its point of origin, drawing its supplies in advance, without encountering appreciable resistance ; but the moment such a wave begins to feel the bottom, the two currents to which it gives rise encounter resistance ; the wave has begun to expend itself in doing appreciable work, which work, if continued, must sooner or later reduce its motion to nothing. The action of the bottom on a wave may be compared to that of a friction-brake on a machine : if applied gradually it will by insensible degrees bring the machine to a standstill ; if applied too suddenly it may produce the same result by a disruption of the machine itself. When, in the case of a wave, the break is suddenly applied in the form of a steep beach, the wave plunges, and is destroyed almost instantaneously. When the brake is applied very gradually, by the bottom shoaling slowly, the wave may be reduced to very small dimensions without breaking at all.

The dissipation of waves without breaking may be occasionally witnessed in the shallow water over mud-banks in estuaries, where the distance the wave has to travel in shallow water is great in proportion to the length of the wave. On the sea-shore, the distance a wave has to travel after feeling the bottom is commonly so short compared with the size of the wave, that the reduction of the wave by the friction of the bottom cannot keep pace with the rate of shoaling of the water.

If the wave survive to reach the shore, as is usually the case, the primary and secondary currents will be found in their relative sequence, the water being drawn off from the shore as the wave-crest approaches.

Having endeavoured to show that there is no evidence that a wave of oscillation is transformed into a wave of translation on nearing the shore (although it gives rise to two distinct currents of translation in opposite directions), I will proceed to discuss the action of these currents : firstly, on objects floating on the surface ; secondly, on movable objects resting on the bottom. It seems clear that, if these currents are equal and opposite, an object under their influence will travel with the one that is applied to the best advantage.

In the case of floating objects, the application of the two wave-currents is influenced by the form that the wave assumes on entering shallow water. The steep anterior wave-slope acts diversely on different objects according to their form and weight.

This fact was brought to my notice by accident. Whilst watching some waves running over a shelving bottom in my tank I observed that a chip of wood dropped into the water at a certain point would recede from the shore, that the cork of a phial dropped in in the same place would go towards the shore, but that a small piece of water-soaked wood would go from the shore with the chip. On this occasion there was a slight surface current from the shore outward, which explained the motion of the light chip ; but this current did not account for the cork going one way, and the water-soaked wood the other. The explanation is as follows :—The outward current, which carried the light chip over the steep slopes of the advancing waves, was unequal to the task of carrying the cork outwards so fast as the latter slid down the wave-slopes shorewards. The cork, by hanging on the anterior wave-slopes, was under the influence of the forward wave-current in each wave longer than under that of the backward, and thus by the mere accident of weight travelled in a contrary direction to that of the chip. The water-soaked piece of wood, though heavier than either chip or cork, did not attempt to surmount the waves. Its specific gravity approximating to that of water, it had little buoyancy, and the waves accordingly broke over it. Thus, whilst exposed to the full force of the backward wave-currents, it partially evaded the forward currents, and in consequence travelled away from the shore, under the influence of the said backward currents. On another occasion I found that when the waves acted on a deep narrow toy-boat sunk to the water's edge, end on, the boat travelled with them ; but that

when the boat was placed broadside on to the waves, she travelled against them.

This result was obtained by wave-action alone, there being no perceptible current. The explanation is the same as in the case of the water-soaked wood. When the boat met the waves broadside on, their crests broke clean over and beyond her decks, and she thus evaded a portion of the forward, or secondary wave-current, whilst encountering the full force of the primary ; but when placed end on, she received the full force of the secondary, or forward current, as the portion that broke over her stern now fell upon her deck, instead of passing over it. These experiments seem to show that a floating object, if under the influence of wave-currents alone, will travel in the direction of that current whose force is applied to the best advantage, either on account of its action (in the case of any particular object) being of longer continuance, or of greater intensity, than that of the opposite current.

It has been stated that in the event of two ships rolling about in a calm at sea being in dangerous proximity, if they be headed away from each other, each vessel will slowly forge ahead, and draw away from its neighbour. In the case of a vessel having fore and aft sails this result might be obtained by the action of the sails flapping backwards and forwards ; but it seems more probable that the slow propulsion of the vessel is caused by the stern, with the swinging rudder, offering a greater resistance to the wave-current impinging upon it than the bow offers to the opposite current. It may be observed that before the days of steam and clipper ships the difference in form between bow and stern was much greater than at the present day.

Perhaps no better proof can be advanced of the truth of my proposition, that a floating object will travel in the direction of the wave-current that is applied to the best advantage, than the example afforded by the natives of Hawaii in their sport of surf-riding. *Harper's Weekly*, of March 17th, 1883, gives the following account of it :—"The surf-riders, . . . plunging beneath the first wave . . . rise beyond it, and swim out to sea till they meet another, and then another, in each case diving just at the right moment to allow the billow to pass over them. If they miscalculate by one second, the surf catches them, and dashes them shorewards,

when they need to be good swimmers to escape being battered on the rocks.”

On the return journey the aim of the surf-riders is to “mount the biggest billow, which carries them shorewards at lightning speed. . . . Should the rider fail to keep his plank at exactly the right angle on the crest of the green billow he will be overtaken by the breaking surf of the wave which follows, and to avoid this must again dive beneath it, and swim out to sea to make a fresh start.” From the above description it would appear that so long as he can avoid the breaking crest the Hawaiian “surf-rider” can swim out to sea encumbered with his surf-board in the face of “great green billows” (that) “come rushing in with overwhelming force,” and that by skilfully taking advantage of the steep slopes at or near their crests he can return to the shore with the speed of the waves themselves.

In the preceding pages I have endeavoured to show that there is no evidence that a wave of oscillation is transformed into a wave of translation on passing into shallow water, and that the observed motions of floating objects can be explained without assuming the existence of such waves of translation. My next step will be to investigate the actions of waves on objects lying within their reach on the sea-bottom, with a view to ascertain whether the wave of translation can be equally well dispensed with in their case. This part of my subject may be considered under two heads, viz.: (1) the action of waves before plunging, and (2) their action after plunging.

The first of these sections has been dealt with incidentally in my Paper on “Ripple-mark,” from which the following passage may be quoted, as recording an observation in point:—

“One fine and almost calm day in the summer of 1881, being at Broadsands, in Torbay, and seeing that the strand was covered with ripple-marks, I proceeded to watch carefully the action of the water, with the view of ascertaining, if possible, the process of their formation. Floating in my boat a few yards from the shore, in about eighteen inches of water, I narrowly scanned the effect of the very gentle swell that was breaking on the beach. I observed that a small shell lying in one of the furrows, instead of being steadily washed shorewards by the incoming waves, was washed backwards

and forwards from one furrow to another; sometimes it would stop on the intervening ridge, and so for the moment help to build it up; at others it would fall over into the furrow towards which, for the moment, it was being propelled; but in no case did it show any tendency to travel continuously in any particular direction along the bottom.”—(*Proc. Royal Soc.*, vol. xxxiv. p. 3.) It will be observed that in this instance the observation was made in very shallow water, at a point close behind the plunging line of the wave, and that even here the primary and secondary wave-currents were so evenly balanced, that though in the case of light objects there was abundant horizontal alternating motion on the bottom, I was unable to detect any sign of one wave-current being more powerful than the other, still less that the incoming swells were in the least degree transformed into waves of translation.

It may be observed that the fact that when the sea-bottom slopes gently from the water-margin the sand is often covered with symmetrical ripples, or ripples with their anterior and posterior slopes equally inclined, from the vicinity of the plunging line to a depth as great as the eye can distinguish them, is sufficient proof that the currents that formed them were evenly balanced.

As the question of the formation of ripple-mark is important, as bearing on the subject of the present Paper, I take this opportunity of calling attention to the valuable Papers of Monsieur C. de Candolle, Professor F. A. Forel, and of Dr. G. H. Darwin, published respectively in the *Archives des Sciences*, and in the *Proceedings of the Royal Society*, all in the year 1883. But I would more especially refer to two earlier notices of observations by Professor Forel in the *Bulletin de la Société Vaudoise des Sciences Naturelles* for February and March, 1878. In the earliest of these notices Professor Forel points out how the shape of sand-ripples formed by waves in the currentless waters of lakes differs from that of ripples formed by running streams. This was one of the points I endeavoured to establish in 1882, in ignorance of the prior published observations of Professor Forel.

The currents set up by a wave plunging on the shore are more difficult to make out than those hitherto considered. Their sequence seems to be as follows, viz. :—

(1). A flow of water from the margin of repose to meet the advancing wave-crest.

(2). A return of the water to the margin of repose.

(3). A flow up the beach above the level of repose.

(4). A return to the said level from the point of furthest reach.

Numbers (1) and (2) seem to be the equivalents of the ordinary primary and secondary wave-currents, whilst (3) and (4) seem to represent the amount of wave force that has not been expended in the plunge on the bottom.

So far as their action on the beach is concerned, numbers (2) and (3) combined may be regarded as forming one current from the plunging point to that of furthest reach; and numbers (1) and (4) as forming one current from the point of furthest reach to that of plunging.

The flow of water down a beach is occasionally spoken of as though it were the recoil of a wave that had previously broken on the shore, whereas the united downward current must be referred to two waves, the lower portion to the approaching wave, the upper portion to the one that has preceded it.

I shall endeavour to show that in their action on beach-material these combined forward and backward currents are nicely balanced.

I shall approach this part of my subject by a description of some observations made on the beach at Oddicombe, in Babbicombe Bay, South Devon.

This beach is well suited for observations on the action of waves free from tidal complications, as, owing to its position in a sheltered inlet in the north-western shores of Lyme Bay, it is protected from all strong tidal currents. It is exposed to heavy seas from only one quarter, viz. between E.S.E. $\frac{1}{4}$ E., and S.S.E. $\frac{1}{2}$ E. When the wind blows from any other direction, it is either off-shore, or blows off the land between Oddicombe and Portland, with a maximum drift of about 40 miles. In the case of an E.S.E. wind the drift is about 191 nautical miles. The general trend of the beach is about N.N.E. and S.S.W.

The following table will indicate the winds to which one part or another is exposed, with their corresponding drifts, in nautical miles. It will be seen that the E.S.E. wind, with the long drift of 191 miles, blows dead on shore. The winds blowing from any point

south of E.S.E. (if they impinge on the beach at all) will tend to drive the shingle to the north, and *vice versa*. In every case winds impinging on the beach from the southward have longer drifts than those impinging on it from the northward:—

Direction of wind. Bearings all magnetic.	Drift in miles.	Direction of wind.	Drift in miles.
N.E. by N.	5	E. S. E. $\frac{1}{4}$ E.	40
N.E.	8	E. S. E.	191
N.E. by E.	9	S. E. by E.	153
E. N. E.	20	S. E.	150
E. by N.	28	S. E. by S.	85
E.	34	S. S. E. $\frac{1}{2}$ E.	68
E. by S.	39		

In the course of the autumn of 1882 I made a series of observations at Oddicombe, roughly measuring the strand on each occasion, and noting the change in the shingle-ridges. At the extreme north-eastern end a cove is partially divided off from the main beach by some large isolated rocks, and in this cove the strand was always composed of shingle (chiefly limestone), extending from low-water mark to the foot of the cliffs, which cliffs bound the beach on the land side, and are only reached by the water in exceptional gales. For the purpose of measuring the strand in this cove, on the 14th October, 1882, I placed together three of the largest beach-stones I could find, just above the reach of the waves. The tide was low and on the turn, and the waves, during the time the level of repose of the water was stationary, had accumulated a ridge, or bank, of small stones. On completing my measurements, I found that with the rising tide the waves had struck my three mark-stones, and that they were now in line, one behind another. Thinking it a good opportunity to observe the action of waves on shingle of different sizes, I stood, watch in hand, to record their action on these three mark-stones. In three minutes the first stone (the one nearest the sea) had fallen down the slope

seawards, the other two being nearly covered up with small stones; in another two minutes number two (the middle one) was carried seawards by a rather heavier wave than usual, whilst number three was nearly out of sight, covered up; in another minute and a-half number three was quite covered up; in two minutes and a-half more, number three was beginning to uncover; in another two minutes it was bare on the face of the slope (not on its summit); in half a minute more it started downwards, and finally, in three minutes more, had travelled so far seawards as to be lost to sight. Thus, in the space of fifteen minutes and a-half, my three mark-stones were carried away by the waves; one of them having been in the meantime entirely, and another partially, covered with small stones. The following note was made on the spot:—"The stones carried away, about 4 or 5 inches long. About 10 yards to eastward, by side of cove, waves not breaking heavily, and not making a ridge, or assorting the stones. The waves, at the point I have been observing, are driving up a ridge of small stones; query, what will they do when they get to the slope of large shingle behind them? Will they drive them (the stones) up the beach, or level the ridge? I placed the largest stone I could lay hands on as a mark, and the ridge passed clean over it, and at 2.20 the stone was carried away seawards by the undertow. The ridge now consists of much bigger stones; . . . to-day, the waves, being very moderate, were carrying the smaller stones up the beach. Wind was S. E., light. It is interesting to observe that, though the weather has been so quiet lately, the small waves have been able completely to demolish any neap-tide ridge: the pebbles forming one sweep from high-water mark to low-water mark to-day."

"20th Oct. (Neap tides.) In little cove at east end a bank of small stones, very steep, at and above to-day's water-line; thence downwards, big beach stones; the dividing line very sharply defined."

"28th Oct. (Spring tides.) Strong N. E. wind; strand, 42 yards; all previous ridges gone, within the distance."

"4th Nov. (Neap tides.) Neap ridge quite new since I was last here."

"14th Nov. (Spring tides.) It having blown hard from S. E. to N. E. yesterday, I went to Oddicombe this afternoon. Found all ridges swept away, except the highest of last winter. . . .

I observed at the east cove, for the first time, that when a wave breaks, and rushes up the beach, the wave-current turns to meet the next wave, towards the sea, long before the advanced portion ceases to flow onward, so that the forward current actually divides into two, one going up and the other down the strand. . . . By the turn of the tide, about 2.30, a steep ridge had been formed between three and four feet high, close to (the) western rock bounding the little cove. Small stones were shot up and over this ridge, and big ones pulled down."

The observations made on the 14th Oct. and 14th Nov. seem to afford a solution of the problem as to the relative destructive and accumulative actions of waves on shingle-beaches, and they reconcile the apparently inconsistent observations of Mr. Palmer and Sir John Coode. It is clear that the destructive and accumulative actions may be going on at the same time. As a matter of fact, they were both going on together on the days referred to, on which occasions the waves were accumulating small stones, while denuding the beach of large ones. I shall presently show how at other times waves will reverse this action, accumulating the large stones while carrying off the small ones.

It is important to note that whilst the plunging waves, observed on the 14th October, were driving forward the small stones and drawing back the large ones, at a distance of a few yards waves that, for some reason, were not breaking so heavily, were not assorting the beach-stones in the same way.

The action of the plunge of a wave in accumulating beach-material can be conveniently studied when very small waves are breaking on a sandy beach, and the sea is not disturbed by swells. It will be seen that the plunge stirs up the sand at the starting-point of the forward current, and that some of this sand is carried forward by the water in suspension. On the turn of the current there is a moment of slack water, during which time the sand falls to the bottom, whence it is not readily dislodged by the return current, commencing as it does gradually, with no preliminary plunge. In the case under consideration, should the sand be mixed with mud, the latter, having no time to settle on the turn of the water, is carried backwards as well as forwards in a state of suspension. Now, it is only necessary for us to transform our summer wavelets by gradual stages into storm waves, for us to

find our fine sand replaced by coarse sand and stones, up to the largest masses the waves can carry forward; whilst at the same time our mud will be replaced by sand, and stones sufficiently small to remain within the grasp of the water.

So far we have seen that the plunge, by supplementing the action of the forward current, causes the latter to accumulate sand or stones in front of it; in other words, to form a sloping beach. But the moment a slope is formed, an opposite or counteracting force is brought into play, viz. gravity, which gravity will tend to cause the accumulated material to roll seaward again. We thus see that the beach-slope, so far as we have considered it, is a compromise between the action of the plunge tending towards the piling up of the beach-material, and the action of gravity which tends to pull it down, the agents being the forward current + plunge, on the one side, versus the backward current + gravity on the other. This is practically the normal state of things on a flat, sandy beach, where the sand is fine and easily saturated. Where the sand is coarse, or the beach-material is shingle, another factor in beach-making is brought into play, viz. the absorption by the shingle of the whole or a portion of the water of the backward current above the level of repose for the time being. In this case we may consider the forces acting on the beach above the level of repose to be:—The forward current + plunge, versus the backward current + gravity – absorption; or, the forward current + plunge + absorption, versus the backward current + gravity.

It will be noted that the absorptive power of the shingle increases gradually from the margin of repose, where it is nil, owing to the shingle being saturated, to the point of furthest reach, where it may be perfect; and that absorption alone would suffice to account for a gradually increasing curve in the profile of a beach above the margin of repose. Such a curved profile is often present at and above high-water mark, where the waves attack the shingle at or about the same level for an appreciable time at the turn of the tide; and more especially is it a feature of spring and neap tides, at both of which times there is not much difference in the high water-level for several successive tides. So far as my observations go, this absorptive action on the part of the beach-material is essential for the formation of the phenomena known as “Fulls,” “Ridges,” and “Sets-off.” With absorption these will occa-

sionally be present whether the beach be coarse sand or shingle; without absorption there can be none.

In the cases we have been considering, the beach-material has been treated as though homogeneous as to size, form, and specific gravity, a state of things that can never obtain in the case of shingle beaches, whose component pebbles usually vary much in size and character.

It will be at once apparent, that the conditions prevailing above and below the margin of repose will differently affect stones that differ in size, form, and weight. The stone that can climb to the foot of the slope that rises so rapidly above the margin of repose may fail in getting higher, whereas a smaller stone, retained in the grasp of the water, on the lesser slope below, may be light enough to mount the steeper incline, and remain there when assisted to do so by the diminution in strength of the backward current by absorption. As a matter of fact, it is not uncommon to find the pebbles composing the steep bank above the high-water margin of repose for the day smaller than those on the strand below. I have already mentioned one instance of this at Oddicombe during neap tides, on the 20th October, 1882; and I find, on reference to my note-book, that the bank of shingle, formed, or re-formed, by the spring tide of October 14th, at Babbicombe, consisted of finer shingle than that on the strand immediately below it. Similar instances could be multiplied. On the other hand, it would be easy to find cases in which, from exceptional causes, the shingle below a bank was smaller than that composing the bank.

The form and specific gravity of shingle affects its distribution by the waves. To take them separately:—It is evident that were the waves to wash a number of pence and bullets up a smooth rock slope, on which the pence could rest and the bullets could not, in course of time all the pence would be found high up on the slope, whilst all the bullets would be collected at the bottom. In the case of beaches where the shingle is partly derived from slate-rock and partly from limestone it is a common thing to find the flat shingle at higher levels than the more spherical. Similarly, on sandy beaches, slate shingle will work its way up the strand by virtue of its superior powers of anchoring itself on the turn of the current.

Sir John Coode has noticed this fact in connexion with the

Chesil Bank. He writes, "It is remarkable, that the large shingle found at about the level of high-water, and such of the large pebbles as may occasionally be found at higher levels upon the Bank, have generally a flatter form than those under water. It is important to notice, that all the shingle near Portland is generally less spherical than that at some distance to the westward, as this proves that it has been longer exposed to the grinding action of the sea." (C. 21.) As this segregation of shingle according to form is a common beach phenomenon, it seems possible that the difference in the flatness of the Chesil shingle may arise from difference of form in the rock-fragments from which the shingle was originally derived. I am not aware that it has been shown that wave-action tends to grind spherical shingle flat; and there is no doubt that spheroidal forms are found in very small shingle.

The effect of specific gravity in influencing distribution I have seen well exemplified in the case of some fine metallic sand collected by the waves at the highest level in one of the coves in Torbay. In this instance the highest and lowest deposits were fine sands, the intermediate expanse of tidal strand being rocky, with some shingle. I may here point out how likely these exceptional cases are to perplex the student of wave-action. In my own case, after having studied beaches for many months, and taken a large series of photographs, I came across a beach in Mudstone Bay, near Berry Head, which seemed to falsify many of my conclusions. Spherical and flat shingle of all sizes was intermixed with sand in hopeless confusion. The explanation was to be found in the surrounding rocks, consisting as they do of limestone, slate, and hæmatite. Shingle derived from such sources naturally differed much both in form and specific gravity. The slate had the advantage in form, the hæmatite in weight, and the result was that the flat slate shingle and the spheroidal hæmatite shingle were evenly matched in their competition for highest place.

We have now briefly considered the effect of waves of different sizes on shingle of different form and specific gravity, but have taken no account of the rise and fall of the tide. Unless the weekly variation in levels, owing to spring-tides and neaps, and the daily variation in levels at high-water and low-water be taken into consideration, some of the commonest beach phenomena may seem paradoxical.

It is not an uncommon thing to find a beach after a gale covered with fine shingle at the higher levels; and again, after another gale of apparently equal severity, to find the same area covered with shingle many times larger in size. For example:—Let Oddicombe beach, during spring-tides, be visited by a heavy gale from the eastward. It will be seen from the table that the sea-drift will be about forty miles, and that the waves will in consequence be comparatively short and powerless. The waves will only throw up the smaller class of shingle; but will throw such shingle to a high level, on account of the height of the tide. A week later, at neap-tides, let the same beach be visited by another gale of equal violence from the south-eastward. The sea-drift will be about 150 miles. The waves will be much larger; they will consequently be able to cast up larger shingle than the waves of the preceding week, and to cast it further. Should the waves of the second gale overreach those of the first, the work of the first will be obliterated; should they just fail to reach them, the result will be that at the higher levels the small shingle will be above, or more remote from, the sea than the large shingle. Reverse the order of events. Let the neap-tide gale from the south-east precede the spring-tide gale from the east. The relative positions of the large and small shingle will now be reversed. The large will now be more remote from the sea than the small.

A somewhat analogous distribution of shingle may arise from heavy waves at low-water reaching as far as smaller waves at high-water.

Mr. Kinahan has stated that on the east coast of Ireland “ground-swells due to S.W. and W. winds have intervals of one, two, five, or more minutes between them, and are much larger than the ordinary wind waves, or the tidal waves, which may be breaking at the same time, rise much higher on the beach, and often at one sweep carry away a mass of materials that it has taken a number of small waves to pile up”—(*Travelling of Sea-beaches*, loc. cit. p. 5.) I have hitherto avoided the use of the term “ground-swell,” owing to the difficulty of ascertaining its precise meaning. Mr. Russell has defined a ground-swell as a wave that is the result, or consequence, of the action of the wind, but which has ceased to be under the influence of the wind (R. 53), and speaks of “the long, low swell, the residue and telegraph of some distant storm”—(*Trans. Brit. Assoc.*,

1837, p. 448). Mr. Kinahan has defined a ground-swell as a wave generated in the Atlantic or Channel, as distinguished from a wave due to the winds blowing directly on the coast—(*Travelling of Sea-beaches*, loc. cit. p. 3).

Mr. (now Sir James) Douglass has referred the travel of shingle to the ocean wave, or ground-swell (P. 45).

Mr. E. Wynne describes Portland as exposed to the full swell of the Atlantic rollers, and considers the said Atlantic rollers might be transformed into waves of translation in the Channel (P. 47).

If the ground-swell be the offspring of a wave of oscillation, it is difficult to see how it is to be distinguished from the ordinary swell, whose action on a beach we have been considering. Nor is it easy to see how it can exert more power than its parent wave. The term conveys the impression that an ordinary swell is meant, travelling in water shallow enough for it to feel the bottom; but I can find no such definition of it. The term is often vaguely understood, which I perceived when an intelligent man described to me the effect on the sea-bottom of an "under-ground swell."

It may be noted, that Mr. Kinahan's long waves of irregular period cannot be ordinary swells resulting from oscillating wind-waves, as their periods are too long and irregular. A few years ago, at one of the British Association lectures, it was confidently asserted, that any wave with a period exceeding twenty seconds must be attributed to some other cause than an ordinary wind-wave.

Many observers, whilst watching the tide rising on the sea-shore during stormy weather, must have been surprised to note the long time that occasionally elapses before the waves reach a given point on the beach a second time. Thinking to observe the rise and fall of irregular waves of this sort best by the currents set up by them in the mouth of an artificial harbour, I made the following observations on February 2nd, 1883, in the mouth of the old harbour at Torquay.

The following is the substance of my notes:—

On the night of Feb. 1st it blew a heavy gale from the southward. On Feb. 2nd I went to the Old Pier Head to observe if there were any "run" in and out of the harbour. I moored a piece of wood about five inches long to a stone, sunk in the harbour's mouth, by a line sufficiently long to allow the wood to pass freely through the space of several yards on the surface of the water. High-water

at 1^{hr.} 30^{m.} P.M. My observations lasted from 12^{hr.} 6^{m.} 30^{s.} to 12^{hr.} 38^{m.} So tide rising and flowing into the harbour the whole time. Wind fresh, right into harbour's mouth (W. by N., over less than one mile of water). The following table gives the times when the currents commenced to flow in and out of the harbour:—

Time.	Direction in which the current commenced to flow.	Remarks.
Hrs. m. s.		
12 6 30	Out.	
12 7 75	In.	Ran the wood under water.
12 9 75	Out.	Ran the wood under water.
12 11 0	In.	
12 13 75	Out.	Sluggish.
12 14 0	In.	
12 15 0	Out.	{ Very strong. Ran the wood under water.
12 16 30	In.	Strong. Ran the wood under water.
12 18 30	Out.	Strong. Ran the wood under water.
12 19 30	In.	{ Ran the wood under for 1 ^{m.} 40 ^{s.} , with an occasional momentary re-appearance.
12 23 0	Out.	Ran the wood under.
12 24 30	In.	Very sluggish.
12 27 0	Out.	Very sluggish.
12 27 75	In.	Very sluggish.
12 29 30	Out.	
12 31 0	In.	Strong. Ran the wood under for 30 ^{s.}
12 32 75	Out.	{ Very strong. Ran the wood under for 1 ^{m.} 5 ^{s.} , without its re-appearing for a moment.
12 34 75	In.	{ A long, steady flow, beginning sluggishly, and then running the wood down for a long time.
12 38 0	Out.	

We have here eighteen full currents in 31·50 minutes, giving the average duration of each current as 1·75 minutes, and the average interval between the waves 3·50 minutes. The outrushes quite obliterated any in-current on the surface due to the wind and rising tide.

These observations made in the harbour harmonize with another set made at Oddicombe on the 4th of November previous. Wind N.W.; very strong off shore. Tide, neaps. Nearly high-water. Beach-slope steep. Sea surging up and down some two or three feet vertical, yet not breaking on the shingle. The run on the beach seemed rather owing to the water surging backwards and forwards than to any very definite swells, though swells could be distinguished sometimes. The water-mark against the eastern rocks seemed nearly three feet between rise and fall; but the change of level caused no break on the beach continually. In this case we see that waves of some kind, some three feet in vertical height between trough and crest, were rolling in upon the beach; but, notwithstanding their considerable height, the rise and fall of the water was so gradual that there was no break or plunge. It will be seen at once that the plunge being a potent auxiliary of the forward current in the accumulation of shingle, and its loss to the forward current being equivalent to a corresponding gain to the backward current, if in any case an accumulation of shingle has been in progress under the action of plunging waves, the occasional intervention of non-plunging waves of equal or greater power must tend towards the removal of such accumulated shingle.

The question arises, what is the cause of these irregular waves of long period? It seems probable that they result from the disturbance of the equilibrium of the water by wind pressure, whereby the water is unduly raised at one point and lowered at another. This phenomenon is well observed in narrow straits between two seas, such as the Kattegat, the Straits of Dover, and the Bosphorus.

In the Kattegat, according to Vice-Admiral Zhartmann (quoted by Mr. Thomas Stevenson), "where the tides have a velocity of 1 to 2 knots, and the common rise is one foot, 'the currents may sometimes, in boisterous weather, continue to run for three weeks the same way, and even to attain the velocity of four knots; and in a furious gale of wind, on the 15th of January, 1818, the water rose

$5\frac{3}{4}$ feet above the common water-stand.' He also mentions that in the Great Belt the velocity is increased in south-east storms from one or two knots to five knots in the narrows of Hasselö, and that north and west winds produce similar effects in the Sound; and he adds, 'Nor is it necessary to this result that the last-named winds should blow home: it is enough that a gale should have swept across the North Sea in that direction for several successive days.'—(*Stevenson on Harbours*, p. 77.)

Major Rennell attributed the loss of "the Britannia East India Ship" on the Goodwin Sands to "a current produced by the running off of the accumulated waters; a violent gale from the westward then prevailing."—(*Phil. Trans.*, 1809, p. 400.)

The currents on the Bosphorus are described as follows by a naval correspondent of *The Times*:—"The main current of the Bosphorus (which) has a strength varying from four to two miles per hour, according to the state of the weather. . . . When a strong north-east wind is blowing, . . . the main stream runs at a greater rate even than the average of four miles previously stated. With a wind from the south, a great change takes place, the course of the current from the Black Sea is checked, and frequently overcome by one at the surface running up."—"Torpedo Experiments on the Bosphorus," *The Times*, 27th December, 1882.)

These instances may suffice to prove that violent winds have the power of piling up the water before them, and of giving rise to strong currents. If, however, a body of water, at any point in the sea, is thus maintained at a height above the normal level, it is only requisite for the restraining pressure to be suddenly removed, or for the pressure to be irregular, for a wave of translation to be generated by nature in a manner analogous to that adopted by Mr. Russell in his experimental reservoir. This reservoir Mr. Russell describes as being twenty feet long, having an additional length of 7·3 inches reserved to form a generating chamber. "By filling the generating reservoir with water to a higher level than the experimental reservoir, while the sluice was closed, on raising it the water descended, producing a wave of which the volume was known."—(*Trans. Brit. Assoc.*, vol. vi., p. 435.)

In nature the accumulated water could be released either by a sudden decrease in the force of the wind or by a change in its direction. Both these conditions are present in storms when the

wind blows in squalls, and either veers or backs. Assuming, then, that by variation in the wind-pressure waves of translation are generated at sea, and thence travel to the shore, it is of importance to ascertain the form under which they reach the shore. Do they continue to be waves of Mr. Russell's first order, or are they wholly or partially transformed into waves of his second order? On the reply to this question depends the action which they will exert on the beach, and the point at which they will plunge, if they plunge at all.

In a Paper read before the Royal Society, Dr. Rankine writes as follows:—"It is known that in deep water all waves left free from the action of disturbing forces tend ultimately to assume the condition of free rolling waves, whose velocity of advance depends on their periodic time. . . . It follows that, if a wave is raised through the disturbance produced by a solid body, that wave will at first travel with a speed depending on the virtual depth of the original disturbance; but as it advances to a greater and greater distance from the disturbing body, the velocity of advance will gradually approximate to the terminal velocity corresponding to the periodic time."—(*Phil. Mag.*, vol. xxxvi., p. 55.) According to Dr. Rankine it would seem that a wave of the first order, a wave of translation, may be gradually transformed into a wave of the second order, whose velocity corresponds with its period. A good opportunity of putting this theory to the test presented itself on the occasion of the Torquay regatta of 1883. The wind was fresh from the westward, off shore. The yachts had to round a mark-boat in smooth water, about half a mile off Saltern Cove, in the bight of the bay. Vessels of fifty tons and over in rounding this mark-boat generated waves sufficiently large to toss about the six-ton boat in which I was sailing. It seemed a good opportunity to observe the character of these waves when they reached the shore after traversing the half mile of smooth water betwixt the mark-boat and Saltern Cove. The water being smooth there was no doubt as to the exact position of the margin of repose. The large waves generated by the yachts plunged on the beach below, or seawards of the margin of repose, and must therefore have undergone, at least partially, transformation into waves of the second order; unless, indeed, it be contended that they were analogous to Mr. Russell's negative waves of the first order, which, however, seems hardly possible.

It may be observed, that Sir George Airy instances the following example of a negative wave:—"The phenomenon of a negative wave is given in great perfection by the paddles of a steam-boat: the first wave which passes away from it being a hollow of considerable depth. We were first made aware of this by observation of the traces made by Mr. Bunt's excellent self-registering tide-gauge on the banks of the Avon, at a short distance below Bristol. . . ."—(*Tides and Waves*, 398.) It may be worth noting, that the waves generated by a bluff-bowed paddle-steamer of the old type are very complicated. While the paddles are making one set on either side, the bows of the vessel are throwing off another set on either side. The latter would resemble those thrown off by a sailing vessel, being independent of the cause of motion, whether steam or wind. The bow-waves being generated in advance of the paddle-waves would precede them to the shore; at any rate, in the case of so narrow a river as the Avon. It seems possible that the traces in question may have been the records of a positive wave of translation, partially or wholly transformed into a free rolling wave in its passage to the river's bank.

It would appear that waves generated by the general equilibrium of the water being disturbed by wind-pressure will reach the shore as waves of translation, subject to modification, if the disturbance takes place at a sufficient distance from the shore. Their peculiar action on the beach will depend on the extent to which they plunge. I have said that, on November 4th, 1882, a vertical rise and fall of the water-level to the extent of nearly three feet caused no break on the shingle at the point I was observing at Oddicombe. A simple backwards and forwards swing of the water of this character, however caused, cannot fail to cut out material accumulated by previous plunging waves. On a subsequent occasion, I made the following note:—Oddicombe, 25th Nov., 1883. "Wind off shore. Disturbed swell cutting out the beach. Angle of one pebble slope 41° , of another 41° ; both in the small cove. This was the maximum angle of repose, as an umbrella drawn lightly across the face of the slopes set the pebbles freely in motion. Moreover, the swells surging up would set dry pebbles free high up the slope I was observing." The two pebble slopes referred to were not curved, their profiles being perfectly straight; and they were clearly ridges or banks of denudation, and not of accumulation.

In our consideration hitherto of the action of waves running on to beaches at rightangles to their trend, we have noticed the various effects produced by swells of different sizes and characters on beach-material of different size, form, and specific gravity; and have seen how greatly the distribution of the beach-material by the waves is affected by the tidal variation in the sea-level. It would seem that ordinary waves, acting on mixed beach-material on a tidal strand, would be sufficient of themselves to form the peculiar beaches described by Mr. Price, where the high-water ridges are separated from large stones lower down by zones of pebbles, gravel, and coarse sand.—(See R., 57.)

In the ordinary case of waves rolling on a beach under the influence of wind, the action of the wave-currents are complicated by currents set up by the wind-pressure on the surface of the water. It is impossible to overrate the importance of the latter currents, as they frequently overpower and obliterate the normal tidal currents of the locality. Prof. J. D. Dana says, that “the forcing of water into bays, whether by regular winds or by storms, causes a strong under-current outward, like that from the tides. This happens when the entrance of the bay is broad, so as to allow of an in-flow over a wide area, while the deep-water channel is narrow. . . .”—(*Man. Geol.*, 3 ed., p. 671.) It will be easy to show that under other circumstances the result will be different. *Prima facie* it is probable that the surface-water will leave the bay at the point, or points, where it will encounter least resistance, whether at the sides or centre, at the bottom or surface, or at two or more of these together. The following instances in the case of Torbay are instructive:—

On January 7th, 1883, during a strong S. W. gale, I found that there was a strong inward surface-current in the mouth of Torquay Harbour (tidal), although the tide was half-ebb. Feeling sure that under the circumstances there must be a strong under-current outwards, I tied stones to a couple of net-corks, with strings about six and eight feet long respectively. On these being thrown into the water, the corks were carried seaward in the teeth of the gale, though in squalls it was blowing furiously. The stones, though small enough not to submerge the corks, offered sufficient resistance to the outgoing under-current to tow the corks out of

the harbour. There was no "run" in and out of the harbour, as on the 1st February, but there were two contemporaneous opposite currents at different levels, the upper one flowing in under wind pressure, the lower one flowing out. Though the tide was ebbing, the current, in the case of so small a harbour, ascribable to that cause would be comparatively insignificant.

On Oct. 19th, 1882, Mr. William Browne, boatman, of Torquay, informed me that he had nearly lost his cutter-yacht "Lapwing" during the southerly breeze of the preceding night, as she had broken from her moorings, and only been recovered by the coastguard as she was going round the New Pier. On pointing out that the yacht must have been going in the teeth of wind and wave, my informant said it was so, and attributed the occurrence to an eddy. As, however, the tidal current at the spot indicated is very feeble, I have no doubt the yacht was under the influence of a strong wind-raised current, working seawards, under the lee of the pier. Mr. W. M. Baynes has favoured me with the following note:—"Jan. 10, 1884. With reference to the undertow in Torquay harbour, I remember watching, about two years ago, what appeared to be a ship's boatfull of water, her gunwales being just awash, slowly travelling from the old pier head across the new harbour in the teeth of a strong south-easterly wind. I think she fouled two or three moored vessels, and, on being pushed clear, determinedly resumed her windward course."

The above cases illustrate the action of wind-raised currents in a tidal harbour, and in one of the minor inlets of Torbay. Torbay itself affords another instance on a larger scale. This bay may be described as a rectangular inlet, some four and a-half miles wide at the mouth, and about three miles deep from mouth to bight. In the bight of the bay the bottom slopes seawards very gently for about a mile, when a maximum depth of six fathoms at low-water is attained, and this depth remains constant over several square miles in the centre of the bay. Easterly winds blow into the bay, and raise the sea. Those from the westward are smooth-water winds, being off shore. Easterly winds are the only ones that can affect the bottom of the bay by either wave-currents or wind-raised currents. During the more than eleven years in which I have taken notes bearing on the action of waves and currents on the bottom of Torbay, I have been much perplexed by the apparent inconsistency

of my observations. Many of these observations, I may remark, bore upon the currents only incidentally, having more especial reference to the occurrence and habitats of uncommon shells. One of these shells (*thracia convexa*), so far as I can ascertain, has only been taken in Torbay alive in one limited locality, viz. off Daddy Hole Plain, on the northern shore. The living mollusc of this species burrows deeply, and is rarely disturbed; but the dead shell, being light, is eminently calculated to be drifted by currents. If, however, this species lives in but one spot in Torbay, as appears to be the case, the occurrence of its shells in the neighbourhood will be a guide to the nature of the currents that affect the bottom. Sundry notes that bear on these currents are collected in an appendix. They may be summarised as follows:—

(1). Shells are occasionally swept from off Daddy Hole to Paignton, in a westerly direction. They are occasionally swept from Daddy Hole to a point off the Orestone, in an easterly direction.

(2). Refuse from the gas-works, and fragments of peat, and masses of seaweed from Torre Abbey, will occasionally find their way to Daddy Hole from the north-westward. Shells and stones will occasionally reach the same spot from the eastward.

(3). One easterly gale will disturb shells living in the ground off Daddy Hole, but not carry them off; another gale of seemingly equal intensity will sweep the whole bottom bare. One gale, or a succession of gales, will roll and kill thousands of cockles off Paignton, without driving them on shore; another gale will send them on shore, and sweep the bottom so clean, that not a valve of cockle will be forthcoming in the usual localities.

(4). A heavy on-shore wind will drive shells on to the beach at Paignton; an equally strong on-shore wind at Meadfoot rarely throws up any: though within a few hundred yards of the latter beach (west of the sea-wall) dead shells collect on the bottom off Daddy Hole in quantity. Among the latter are occasionally found limpet shells, which have probably come from the shore (the alternative points of derivation being outlying islets), and beach-shingle that must have come from the shore.

(5). A strong easterly wind usually reverses the normal inflow of the ebb-tide along the northern shore of Torbay, but occasionally seems to intensify such inflow.

I may instance one extraordinary case of a heavy object being carried away seaward in the teeth of the waves. Some years ago the heavy wood and iron door of the sewer outfall at Torre Abbey was trawled up by a Torquay fisherman, Enoch Stockman, off Meadfoot Sands, and towed back to Torquay. The incident came under my notice, as Samuel Stockman was dredging with me at the time, and called my attention to his son having got hold of something heavy. Having asked Enoch Stockman to let me have his own account in writing, he has sent me the following note:—"I cannot tell how many years ago, I cannot tell in what month, I caught the shout (*sic*). I believe the Great Rock was a sail breadth open in the Thatcher. We were just abreast of the sinker, shagstone drawing inside Dyer's quarry." The important facts are that Stockman trawled the "shout," which he estimated at some seven feet square, from the bottom of the sea, some 2500 yards from its point of derivation. The average course followed by the outfall door to the point where it was trawled was from about N.W. to S.E. The waves that set it in motion must assuredly have come in from about the opposite direction.

The observations recorded above indicate bottom currents in Torbay that vary greatly in direction. I venture to suggest that such currents may be caused by wind-formed currents in the English Channel of varying depth and intensity. Winds from any point north of E. by S. have a sea-drift before striking the mouth of Torbay, of about 40 miles and under. Winds from any point between E. by S. and S.E. have a drift of 145 to 190 miles.

Thus, two easterly gales of equal intensity will be accompanied by currents of short or long drift, according as they blow from points north of E. or south of E. The gale with the longest sea-drift will create a deeper current than that with the shorter drift, both on account of the greater time during which it acts on the water, and on account of the heavier seas raised in the greater distance traversed by the wind, the deeper wave-hollow allowing the wind to act on the water at a greater depth below the level of repose. Now, it is clear that the depth of a current entering a bay is of great importance in respect to the action brought to bear on an object lying on the bottom. If such a current be deep enough to affect the bottom directly, the motion imparted to the object will be in the direction of the main current; but if the current be not

deep enough to reach the bottom, but passes over it as a surface current, the object will escape any direct action, and may even be impelled in a direction contrary to that of the main current by an under-current moving seawards, to balance the main surface-current, moving shorewards. Thus the difference of a few feet in the depth of a current may make all the difference in the direction in which a light object on the bottom may travel under its influence.

The action of the waves on shells, such as the cockles already referred to off Paignton, lying, as the latter occasionally do, in six-fathom water, at the foot of the slope rising towards the shore, would naturally be much affected by the depth of any surface-current that might be driven into the bay. If deep enough to reach the shells, the wind-current would unite with the breakers in driving the shells up the slope shorewards. If not deep enough to reach them, the surface-current shorewards would generate an under-current seawards, which would oppose the shoreward impulse of the breakers. When such conflicting forces are at work it is not surprising that shells should be cast on shore by one gale and not by another, or that they should be abundant on certain beaches, whilst almost, if not quite, absent on others in the same neighbourhood.

It seems unnecessary to adduce further evidence in proof that a wind blowing into a bay may set up currents both in its own direction and in a direction opposed to its own. The fact is one of common acceptance, as evidenced by the statements of Messrs. Dana and Geikie in their respective manuals, as already quoted, viz. "The forcing of water into bays causes a strong current outward," and "A prevalent wind, by creating a current, will cause the shingle to travel coastwise." But in this admitted action of the wind in causing currents we have, as it appears to me, an explanation of the apparent paradox, that winds and waves occasionally appear to drive large pebbles further than small, and at other times small pebbles further than large.

In the passage already quoted (P. 31), Admiral Spratt bears witness to the fact that he has seen small clinkers travel along a coast faster than large ones; but all sizes travelled in the same direction. Mr. W. Topley, describing the beaches between groynes on the coast of Sussex and Kent, stated that "in each separate area it was found that the largest pebbles had been carried . . . to leeward, and to the summit of the beach" (P. 25). These cases

can be easily paralleled. They represent respectively that action of wave and current that strips a beach of all its contents, and that distributive action which may part the large shingle from the small, and the sand from both. Mr. Godwen Austen, describing the manner in which the materials of long lines of beach may be entirely swept away, stated that he had "seen, at one time or another, nearly every portion of our south coast in the condition of bare rock without sand or shingle. . . ."—(*Q. J. G. S.*, vol. vi., p. 72.) I have myself described an extraordinary instance of stripping in the case of the sands at Blackpool, near Dartmouth, in April, 1881, when the eastern half of the beach was laid bare.—(*Trans. Dev. Assoc.*, vol. xiii., p. 345.) Extreme cases of stripping, such as that at Blackpool, cannot be attributed to mere wave action during severe gales. Gales from all quarters are common enough on the south-west coast; but, though acquainted with Blackpool beach for more than five-and-twenty years, I have never heard of the eastern end being stripped except on the occasion referred to.

One of the keys to the problem of the distribution of beach-material will probably be found in the fact that, whereas shingle on a beach must go with the wave, sand must go with the strongest current. If wave and current unite, the beach will be stripped; if they act in opposition, the beach-material will be distributed.

A good instance of shingle and sand travelling in contrary directions will be found on the north-western shores of Lyme Bay, between Hope's Nose and Teignmouth. There is good evidence that between these points shingle travels from S. W. to N. E., that is, from Hope's Nose towards Teignmouth, and that sand travels from N. E. to S. W., the contrary direction.

On the 23rd October, 1880, there having been a heavy easterly gale on the preceding day, I visited Babbicombe, and was there informed by the coastguardsman on the Down that the beach had been washed away from the Babbicombe side of the bay to the Oddicombe side, *i. e.* from S. W. to N. E.

Before the gale referred to, a little cove, behind the Cary Arms Inn at Babbicombe, contained sufficient shingle to accommodate a bathing-machine, as is shown in a photograph taken by Messrs. Frith & Co. in 1878, and described as the "Bathing Beach, Babbicombe." A photograph taken by myself in January, 1884, depicts it as a gully between the rocks, strewn with huge stones,

devoid of all shingle, and as unlike a bathing-cove as any place can be. The shingle in this cove was derived from quarries on the south-west, which were largely worked some years ago. We have in this case an instance of a beach on the north-western shores of Lyme Bay, between Hope's Nose and Teignmouth, being suddenly destroyed by the shingle travelling *en masse* to the northward. On Oddicombe beach the largest shingle collects at the north-eastern end. There is little doubt that the bulk of the Oddicombe shingle came from the quarries to the south-west, already referred to; but the most incontestable evidence of the travel of large fragments of stone from S. W. to N. E. will be found in the "junctions" of greenstone and slate, traversed by calcite veins, which junctions are occasionally picked up on the beach up to its extreme north-eastern end, and are all derived from the coast between the S. W. end of Oddicombe beach and Babbicombe beach, where the greenstone rock bursts through the Devonian slate, forming a junction with it. Evidence of the south-western travel of the sand will be found in the direction of the sand-spit at the mouth of the river Teign, which stretches from the eastern towards the western bank of that river; also from the persistent tendency of the sand derived from the crushed shingle to collect at the south-western end of the said Oddicombe beach, one of the longest and most important beaches between Teignmouth and Hope's Nose. The point to which I desire to call attention is that, between Teignmouth and Hope's Nose, sand has been observed to travel in a south-westerly direction, and shingle in a north-westerly direction, and that two observers, judging the one from the sand, the other from the shingle, would arrive at conclusions diametrically opposite as to the general driftage of beach-material on the north-western shores of Lyme Bay. Such a difference of opinion, as we have seen, has actually arisen in the case of the Chesil Bank, on the eastern shores of the same bay; those observers who have based their conclusions on the existence of sand to the westward of the shingle, and on the gradual diminution in size of the shingle from east to west, having contended that the driftage must be towards the sand from the shingle; whereas those who have more especially observed the action of waves on large beach-stones have contended that the shingle must have travelled from the direction of the sands. The difficulty will vanish when it is seen that both sets of observers may

be right, and that under certain circumstances sand and shingle may be travelling across the same line in contrary directions. It may be observed here that, in the shingle-bank thrown up at Oddicombe by a severe gale from the southward and eastward, on September 1st, 1883, the shingle gradually decreased in size from N.N.E. to S.S.W. In this case there was no doubt whatever that the shingle was larger to leeward than to windward.

Lyme Bay, with its numerous minor indentations, between Portland and the Start, has presented many knotty problems for solution concerning the travel of beach-material. Of these there may be specially noted the reversed directions of the Teignmouth and Exmouth sand-spits, though but a few miles apart, the assortment of shingle in gradually decreasing or increasing sizes, as the case may be, and the exceptional height of the Chesil Bank above mean-tide level. It seems likely that the problem presented by any beach in Lyme Bay or elsewhere will yield to investigation if it be treated on its own merits, without regard to the possibly, to all appearances, contradictory phenomena presented by neighbouring beaches, in which the beach-material, and the conditions of wave and current action are not precisely the same. It is not, perhaps, too much to say, that on no two contiguous beaches, nor at the two ends of any one beach, are these conditions identical, though the difference may be but slight. In Lyme Bay the difference in the conditions of wave and current action on the eastern and western beaches is very great. From near Sidmouth to Portland its shores are more or less exposed to waves and currents generated in the Atlantic, whereas no point, even in Start Bay, though upwards of forty miles further down Channel, is similarly situated. Thus, whilst the western beaches encounter their heaviest seas from the eastward, the eastern beaches encounter their heaviest from the westward, and there is no comparison between the power of the waves in the two cases. Even so, the difference in vertical height between the eastern and western beaches may seem unaccountably great, though much of the difficulty vanishes when we remember that the western waves act in concert with ocean-generated surface-currents and an abnormally high water-level in the Channel, whereas the eastern waves are only supplemented by a Channel current, and have their action diminished by an abnormally depressed water-level.

It may be observed, that the strength of the tidal currents at Portland can throw no light on the exceptional height of the Chesil Bank above the ordinary spring-tide level, however much the tidal currents, owing to the peculiar conformation of the coast, may augment the height of such ordinary level.

The question of the motion of shingle and other objects along the sea-bottom at a distance from the shore presents as great difficulties to the student as its motion on and along sea-beaches, owing to authorities being at so great variance both as to the amount and cause of such motion. On the one hand, we have Mr. J. M. Rendell expressing his opinion that shingle can scarcely be moved by the heaviest waves at greater depths than three fathoms, and on the other, Mr. J. T. Harrison speaking of "stones detached from the rocks" being "carried along the coast in deep water, knocked about here and there, and having their edges rubbed off in all directions" (P. 38). We find Mr. F. Wynne going still further, and maintaining that "the occurrence of any sort of rock as a pebble" on the Chesil Beach proves "the existence of a more or less exposed reef of that rock between the commencement of the shallow water of the Channel and this beach"; and further, that "if syenite was found, then syenite existed in the bed of the Channel, perhaps as far as the entrance of the Bay of Biscay" (P. 47). Between these two extremes all shades of opinion are held as to the power of waves, tides, and currents to propel shingle along the Channel floor.

With respect to the existence of motion at considerable depths, the facts recorded by Messrs. Douglass, Stevenson, and Winder seem conclusive:—*e.g.* the lobster-pots filled with sand and shingle during heavy swells in thirty-fathom water: the coarse sand thrown on to the lantern-gallery of the Bishop Lighthouse (P. 46): the relation of the depth of water in which mud is found to be deposited to the size of the waves that affect the locality (*Stevenson on Harbours*, 2nd ed., p. 21): the passage of a piece of iron plant round Dover breakwater in ten fathoms, whose track was traced by Mr. Winder, when himself on the sea-bottom.—(Kinahan on Sea-beaches, *Proc. Roy. Irish Acad.*, 1879, p. 203.) In addition to these may be cited the jar nearly full of sand and gravel trawled off the Start (*Trans. Dev. Assoc.*, vol. xii., p. 73, and *Proc. Royal Society*, vol. xxxiv., p. 10.); and the soda-water bottle trawled in about forty fathoms off the same headland, whose condition, as

evidencing alternate periods of repose and disturbance, I have fully discussed elsewhere.—(*Trans. Dev. Assoc.*, vol. xv., pp. 359-365.)

While the above facts testify to the existence of occasional motion on the bed of the English Channel, the following facts negative the possibility of such motion being due to any violent currents of translation that affect the surface of the bottom:—

(1). The occurrence of angular shingle at various points westward of Scilly.—(Map of English Channel, R. A. C. Austen, Q. J. G. S., vol. vi.)

(2). The perfectly unworn state of chalk flints trawled fifteen or twenty miles off the Start and Eddystone. It may be observed, that two specimens, weighing respectively 3 lbs. 2 oz. and 2 lbs. 14 oz., taken twenty miles south-west of the Start, were unrolled. A small flint, 8 oz. in weight, taken fifteen miles south-west of the Eddystone, was very slightly abraded, though one weighing 6 lbs., taken five miles further to the south-west, was perfectly unrolled.—(*Trans. Dev. Assoc.*, vol. xii., p. 293, and “Corrigenda,” vol. xv., p. 365.)

(3). The occupation of the Channel-bed by an extensive fauna, which could not exist in the face of currents sufficiently strong to sweep along sand and shingle.

The advocates of powerful waves of translation, whether tidal or otherwise, have never disposed of the objection that the Shambles Shoal off Portland, composed as it is of light comminuted shells, could not possibly exist in the face of any such waves of translation. Waves that could sweep shingle up Channel to Portland would naturally sweep away every vestige of a shoal composed of such light material, at any rate for a time. But it is well known that the shoal in question is to all intents and purposes permanent. Sir John Coode has described it as “an immense bank of fine broken shells, lying south-east of Portland, which was now in the same condition as when surveyed by Mackenzie, about one hundred years since, and having now, as then, a depth of only 11 feet of water over the crest” (P. 50).

The persistence of the Shambles has been a perplexity to scientists from Sir H. de la Beche’s time up to the present, and, so far as I am aware, the advocates of the wave of translation theory have never attempted to account for the phenomenon.

The persistence of shoals and sandbanks in the face of waves, however heavy, presents no difficulty so long as the waves are

the ordinary sea waves of oscillation. A simple experiment in the artificial formation of ripple-mark illustrates incidentally the action of waves on a shoal. The experiment, as I have often made it, consists in placing an inverted flower pan in an experimental tank, and causing artificial waves of regular period to roll over it, and act on sand strewn upon its surface, or on a pane of glass resting on it. At first sight the waves seem to have no power to wash the sand off the pan, so little is the translatory motion in any direction. Occasionally such a motion can be detected. On one occasion, when experimenting with sand strewn on a gelatine film ⁵ (a convenient method for preserving the ripple-marks when made), I observed the sand-ripples evinced a tendency to travel forwards. On investigation, I found that the resultant forward current over the bank arose from the balance between the primary and secondary wave-currents being disturbed by the greater depth of water at the sides of the bank. I have since found that an inward current over a raised surface can be transformed into an outward current by raising the sand at the sides of the bank, and thus converting the quondam bank into a depression.

In the case of waves of oscillation we have seen that the water below the level of repose travels to meet the advancing wave-crests, and with the waves when above that level. Thus, in the case of a sandbank just level with the surface of the water the whole of the wave-action affecting it must be forwards, as during the backward flow the surface of the bank, *ex hypothesi*, will be high and dry. In such a case, however, the forward current cannot be fairly described as a wave of translation; it is but one half of a wave of oscillation, whose other half has been applied elsewhere. The result of such unbalanced action will be the depression of all the bank to a limited depth below the surface of the water, unless the sand be accumulated by currents faster than the waves can dislodge it. Marine shoals and sandbanks are commonly the joint production of wave-currents and tidal-currents. The neutral wave-currents keep the component parts in motion, whilst cross-tidal-currents accumulate them. Occasionally an important sandbank results from these combined effects; more commonly the result is a collection of dead shells, or shell-sand, known only to the trawler-man or dredger.

⁵ An ordinary photographic dry plate.

APPENDIX.

NOTES.

1872. November 22, . Three valves, *Thracia convexa*, under Daddy Hole.
1872. November 28, . Various shells, including live *Lucinopsis undata*.
1871. December 12, . Live *Cyprina Islandica*, one *Thracia convexa*, and other shells.
1873. February 1, . Heavy easterly gale.
1873. February 4, . Paignton Sands strewn with *Cardium tuberculatum* and *C. aculeatum*, curiously assorted.—(*Trans. Dev. Assoc.*, vol. viii., p. 183.)
1873. February 14, . Had a haul under Daddy Hole, and caught nothing but weed.
1873. May 12, . . Caught dabs (by hook) feeding on red arms of spinous cockles. A few weeks previously, had myself dredged a great many cockles dead and dying, and totally denuded of spines.
1874. January 13, . Dredged about 100 cockles off Paignton. All rolled, excepting new growth sufficient to carry two, and in some cases three spines on each rib. In many cases the shells had been again rolled, and the process of repair recommenced.
1874. January 26, . Took 18 species of shells under Daddy Hole.
- „ „ 29, . Took 31 „ „ „
- „ March 4, . . Fine valve of *Thracia convexa* on Paignton Sands.
- „ May 12, . . . Took a good specimen of *Thracia convexa* (dead) in “The Pit.”
1878. April 18, . . Five hauls on cockle-ground off Paignton. Did not take a valve of cockle of any sort.
- „ „ 27, . . Told that the cockles were ashore at Paignton. Found the sand strewn with them.
1880. October 15, . Dredged off Daddy Hole. Dredge almost empty. Plenty of dead shells in “The Pit.” Torbay seems bare of shells. After a week’s easterly breezes, with rough sea, there are scarcely any fresh cockles on Paignton Sands.

1881. October 19, . Easterly gale.

„ „ 31, . Went out to ascertain effects of recent gales on bottom of bay. Between Torquay and Paignton some very small cockles, with spines perfect, and showing no signs of damage.

I have elsewhere recorded how severely these gales had dealt with some of the larger shells and ascidians in the bay (*Proc. R. S.*, vol. xxxiv., p. 4); and the occurrence of these delicate little cockles in shallow water, at one of the most exposed points in Torbay, was at the time an inexplicable enigma.

1881. December 25, . My boatman brought me some adult *C. aculeatum*, taken in herring-nets off the Gas-works (Hollowcombe). During the past year I have taken none in the dredge.

1882. October 3, . . On the "Gas-house Sands" (Hollowcombe) picked up an old iron gas-pipe covered with solid tar-stuff. Had it in my hand some time, and took particular notice of it. On rowing off to my sailing-boat, we ran off to a spot between Paignton and Torquay, where small cockles were abundant last year. Found none. Then on to Daddy Hole. On the way I pointed out to my boatman that the reason shells collected there, and at Fishcombe (on the south side of the bay), must be owing to an under-current during easterly winds. Off Daddy Hole found the usual shells collected. The second haul of the dredge brought up a rolled piece of tar-stuff about the size of my fist. Next haul brought up a piece of peat from Torre Abbey, and a handful of small coke the size of walnuts. The Gas-house Sands have been covered with coke all the summer.

1882. October 12, . . Dredged under Daddy Hole. An immense number of dead shells, one old *patella*, some clinker and cinders, apparently from steamers.

1882. October 13, . . Meadfoot. Searched high-water mark carefully, from slipway to rocks at west end, and did not find a single shell, except one unrecognizable fragment, as smooth as china.

1882. November 13, . Fresh N.E. gale. Whilst observing the beach at Meadfoot, a barque ran into the bay. Went round to harbour to watch her. George Cumming, a boatman, discussing her position, remarked that in easterly winds there was a continuous flood-tide (*i.e.* east-going current) along the shore. Sometimes a "regular current" past the pier head. Same morning, I watched through a telescope a number of black duck swimming just on the edge of the breakers off Paignton. Sometimes the seas would break outside them, when they would dive, and come up again in about the same place. (See Yarrell, *Brit. Birds*, vol. iii., pp. 325, 327.)

1882. November 17, . Tried ground under Daddy Hole. Dredge brought up half a bucketful of stones. It would appear that the late N. E. gale must have caused an inset on the north side of Torbay. My boatman volunteered the remark, that on the day the barque that took shelter off Torquay Pier sailed away, the seine boats shot their seines off "London Bridge," expecting an east-going current as usual in easterly winds; but that their seines were so rapidly swept to the westward, that they had to haul them in at once, "end on." Tried two hauls across the line, in which I took the stones, but could not hit them off again. They must have been very local. On subsequently examining the stones dredged on the 17th, I found amongst them upwards of 1000 shells and fragments. These shells, in their general aspect, differed materially from those usually found off Daddy Hole. They differed both as to species, character, and condition. Among them were nine specimens of *Cypræa europæa*, nine specimens, or fragments representing individuals, of *Patella vulgata*, *Helcion pellucidum*, *Fissurella græca*, *Littorina obtusata*, and a fragment of an adult *Cardium norvegicum*. Fragments of a balanus were abundant. Many of the shell-fragments consisted of small pieces of thick shells, such as can commonly be met with to the eastward of Daddy Hole, especially off the raised beach, where, at one spot, the bottom consists of broken shells; but such as are not usual on the sandy bottom of Daddy Hole, or to the westward thereof. The stones were similar in appearance to the shingle of Meadfoot beach, and it might occur to some that the shells had come off that beach. But I have already pointed out that a special search on October 13th, a month previous to the gale referred to, resulted in but one worn fragment being found there; and I may add that a second search, on March 21st, 1883, from the slipway to the western rocks was not repaid by a single fragment of any sort. The portion of the beach examined on both occasions was that part, west of the slipway, where the waves can expend themselves on a natural beach, uninfluenced by the sea-wall.

XXXII.—NOTES ON THE MICROSCOPICAL CHARACTER OF
THE VOLCANIC ASH FROM KRAKATOA. BY J.
JOLY, B. E., Assistant to the Professor of Engineering,
Trinity College, Dublin. PLATES XII. and XIII.

[Read, March 17, 1884.]

ON the 26th of August, 1883, the Norwegian barque *Borjild* (Captain Amundsen), on her way from Cherribon to Anjers, cast anchor off the east coast of the Great Kombuis Island, some seventy-five miles to the north-east of Krakatoa. Here she remained during the period of the eruption; volcanic ash falling on her decks from 6 A.M. to 6 P.M. on the 27th. On that day, at 2 P.M., the darkness, due to absorption by the great layer of dust above them, was described as being so intense that mutual recognition by vision was impossible.

In the month of February, during the stay of the *Borjild* at Dublin, a portion of this ash was, through the kindness of Mr. Hogg, of Trinity College, obtained by the author. The examination of this ash forms the subject of the following notes.

Mere inspection with a lens shows the ash to consist principally of vesicular fragments of pumice interspersed with vitreous and crystalline particles. Before dealing with these it is interesting to note the presence, as of accidental origin, of

Sodium Chloride.—The presence of this substance may readily be demonstrated by taste; or by immersing in distilled water and testing. Mr. Moss, who first called attention to it, estimated it to be present to the extent of 0·8 per cent.

Organic Marine Remains.—Those noticed were foraminifera, of which some quite perfect shells were found, and also fragments of starfish (identified by Professor Sollas). Similar remains were removed from the external cells of a specimen of the “floating pumice,” picked up by the *Borjild* in the Straits of Sunda.

Perfect identity, mineralogically, seems to exist between this floating pumice and the ash. Larger crystals may, however, be obtained from the former than occurred in the latter. Feldspars

3 mms. long were found protruding from the abraided surface of the block pumice. In the dust they rarely exceed 1 mm. in length. The formation of the dust by mere pulverization of the pumice seems a most likely supposition.

With regard to the *modus operandi* of preparing this dust for the microscope, it may be useful to note that while it was found that mere shaking up with water, and pouring off before complete settlement, served to remove the lighter fragments of pumice, complete separation was only readily effected by the following method:—

Into a glass tube 1 m. long and about 4 cms. in diameter, closed at one end and filled with water to the brim, the partially cleansed dust is introduced and allowed to settle. A slip of glass is now pressed on the open end, and the whole rapidly inverted into a shallow dish containing water. The denser particles descending most rapidly through the column of water in the tube reach the dish first. When the more slowly moving particles are observed to have nearly attained the dish, a movement of the tube to one side effects the desired separation.

One and all the constituents of this ash present under the microscope a spectacle of the most extreme interest and beauty. The almost unlimited minuteness of the vesicular structure of the pumice, the endless variety in form and colour of the amorphous fragments, the exquisite perfection of form exhibited by the minute crystals of magnetite, of pyrites, of pyroxene and of feldspar; the nebulae of enclosures in these last, and their delicate overspreading lace-work of still adhering vesicular glass. Here are seen small crystals enclosing many others, and these again, still others; while often with the symmetry of the crystal the vitreous inclusions, amber-yellow, range in concentric zones in the translucent depths.

But if this be a wonderful spectacle viewed by ordinary transmitted light, the beauty and wonder of it are a thousandfold increased when, rotated in polarized light, each feldspar crystal reveals its molecular symmetry in flashes of changing colour beside which the richness of the emerald, ruby, or sapphire, would pale. The abundance of twinned crystals add much to the effect: and now, also, many fragments passed over before as less interesting put in their claim to symmetry, and shine not less brightly than those displaying facet and angle. Many hundreds of square miles

were thickly covered with this ash around the scene of the eruption, and these miracles of structural perfection doubtless abundant in every grain of it.

Dealing with the constituent minerals in the order of their abundance, the *Feldspars* first claim attention. They will be at once identified by their colourless transparency; specimens exhibiting a milky decomposed appearance, or showing diffused iron stains of brown-yellow tint being rare. In the latter case, also, a few moments' immersion in hydrofluoric acid generally shows the colour to be confined to the covering of pumice glass adhering to the surface of the crystal.

This covering of pumice, most noticeable in the feldspars, but also overspreading pyroxene crystals, is obviously the remains of a former matrix of highly vesicular glass; being occasionally even recognisable as the fragments of bubble walls; sometimes projecting along the edges of the crystal, giving a fringed appearance, or, again, overspreading the more developed faces forming a hexagonal pattern often of great beauty and regularity. The appearance, indeed, suggests at first sight such markings, cohesion figures, as are formed when two flat surfaces compressing a viscous material are suddenly separated. It will be found, however, that crystals removed from the block pumice carry with them just such remains of the matrix.

Optical examination could not safely be undertaken till this coating had been removed by hydrofluoric acid. This operation demands care, as the feldspars themselves are soon decomposed by the acid.

Two principal forms of feldspar crystals occur; a columnar and a tabular, the latter most abundantly.

That the tabular variety is in general plagioclastic is certain. Polysynthetic lines of twinning are frequently observed with polarized light, sometimes crossing at right angles. More generally these lines traverse the crystal longitudinally. Carlsbad twinning is common, extinction occurring at some 8 or 9 degrees at either side of the medial line. This form of twinning is seldom absent in crystals of the columnar variety. If such tabular crystals as exhibit this medial twinning line be considered as of the same nature as the columnar crystals, a plagioclastic character might be ascribed to the latter, as just such tabular crystals will be

met superimposed and twinned with others exhibiting undeniable plagioclastic characteristics. At the same time, many orthoclastic peculiarities are, as will be seen presently, noticeable in the columnar crystals.

Little or no cleavage is apparent in these tabular crystals. Extinction does not occur parallel to the edges of the dominant faces—apparently macropinacoids. Want of properly furnished instruments forbids the author entering at present further into the anomalies presented by these plagioclastic feldspars. They are quite insoluble in boiling hydrochloric acid—or after some days' cold digestion in the same.

The second variety, if it may be considered as such, may be described as columnar, with nearly equally developed faces seemingly at right angles to each other. Four pyramidal faces terminate one or both ends. This pyramidal termination is occasionally truncated, giving a fifth terminating face at an angle other than 90° with the zone axis of the prismatic faces. Marked rectangular cleavage on one set of these faces; direction of cleavage apparently parallel to pyramidal planes: generally a single medial twinning line on the other set of prism faces. Extinction for the first set of faces (those showing cleavage), parallel to the longitudinal axis of the crystal. For the second set, symmetrically on either side of twinning line; seldom more than 15° on either side. A specimen wanting the twinning line extinguished on these faces at 16° with the longitudinal axis; parallel to it on the adjoining faces of the same zone.

Viewed when resting on one of its longitudinal edges, characteristic border lines displaying vivid prismatic colours become apparent between crossed nicols. Polysynthetic surface striations might account for this appearance.

The photograph (Pl. xii. fig. 1), taken with nicols crossed, contains a couple of these crystals removed from the floating pumice. The crystals, adhering together, rest on their edges and display well the border lines just mentioned. (Figure 1A. Pl. xii.)

Flame tests indicate for such crystals a percentage of potassium comparable to that of orthoclase. If they, indeed, are sanadine, there is evidently a peculiarity in twinning. Although good crystals are scarce, fragments are numerous. They will be detected by their marked cleavage.

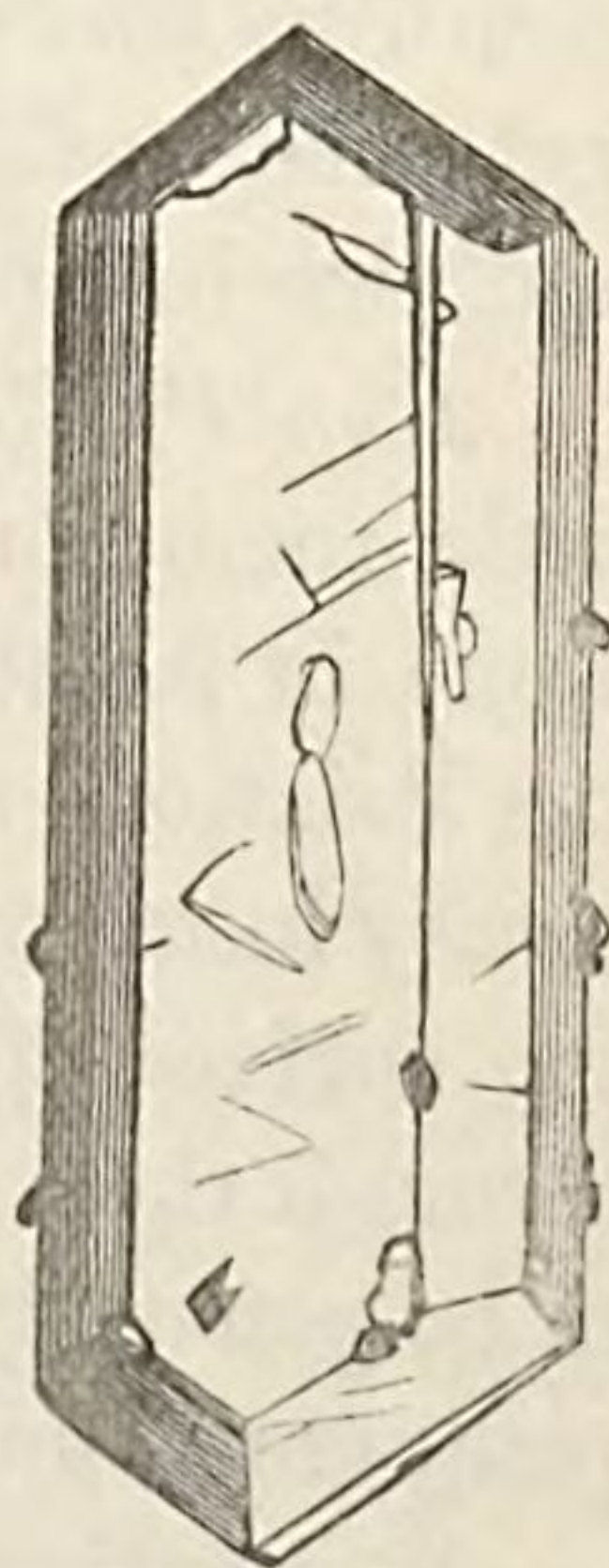
The tabular variety is represented in the photographs by the remaining crystals shown in the photograph (Pl. xii. fig. 1), which is taken at an enlargement of about 20 diameters. A very good specimen is shown, magnified 35 diameters, in Plate xii. figure 2: enclosures, vitreous, containing crystals, will be noticed. Growth striations and the lace-like pattern of adhering-glass are also shown. The presence of growth striations or zones, very common in these feldspars is generally assumed to indicate a more or less tranquil formation.

The *Pyroxenes* are a noticeable feature in this ash. The rhombic variety is by far the most abundant, indeed the monoclinic is scarce, and present usually in badly developed or small crystals. A group of the rhombic pyroxenes is shown in Plate xiii. figure 4. Enlargement 15 diameters.

These crystals are olive-green to brown in colour; translucent. Their pleochroism is well marked, the colouration following the order assigned to *Hypersthene*, by MM. Fouqu  and Levy (*Min ralogie Micrographique*): that is, parallel to their principal axis dark-green, parallel to the macrodiagonal, red, with intermediate tints of brown.

This mineral will be found to extinguish parallel to its pinacoidal faces, not alone when viewed longitudinally, but also when placed with its principal axis in a vertical position between crossed nicols. Treating in this way the nearly central crystal, the one exhibiting a pointed termination at each end in the group (Pl. xiii. fig. 4), the exquisite perfection of its minute form became apparent.

This crystal, which parallel to its longitudinal axis shows pinacoidal and prismatic faces, the former dominant, shows four principal terminating planes, apparently octahedral. Two other faces, brachydomes seemingly, are well defined. Other minute faces are visible, scarcely determinable. The adjoining woodcut, a sketch of its appearance viewed in a direction inclined a little upwards, and to the left of the brachydiagonal, shows some of its faces.



The photograph (Pl. xiii. fig. 3) conveys but a faint idea of a very

beautiful specimen—consisting of three interpenetrating crystals. Their faces are very perfect, and extinction for each crystal is parallel to its longitudinal axis. These are soluble in hydrofluoric acid after long immersion. Just such crystals are depicted in the *Minéralogie Micrographique* of MM. Fouquè and Levy, as extracted from the lavas of Santorin of 1866.

The monoclinic pyroxene, *Augite*, which so closely resembles the hypersthene in appearance will be found to be only feebly or not at all polychroic. Extinction occurs at some 30 to 37 degrees with the principal axis. This angle is stated to vary with the amount of iron present in the mineral. It is never so low as to confuse it with hornblende.

In general its crystals are of a brighter green colour than the greenest of the hypersthene. They, also, are slowly soluble in hydrofluoric acid. Crystals of hypersthene 4 mms. long were picked up: the augite rarely was found above 1 mm. in length. Similar crystals fell in Norway in a volcanic ash from Iceland (Fouquè and Levy, *op. cit.*).

Magnetite occurs not alone abundantly as inclusions in the various crystals, but is plentiful as minute octahedrons exhibiting the usual twin forms with octahedral composition face. It shows a fine black, splendant, metallic lustre; occasionally bluish and even like that of anthracite. An electro-magnet enclosed in a long test tube was found of much service in removing it from solutions, and also in isolating the pyroxene containing this mineral.

Iron Pyrites is present in such characteristic forms as to leave little room for doubt as to its identity. It will be observed not alone in isolated fragments, little aggregations of cubes showing the striations at right angles on adjacent faces, and exhibiting the brassy lustre of pyrites, but also, imbedded in and protruding from the surface of some of the rough amorphous fragments scattered through the ash. In good light the faces of these crystals are seen to be generally pentagonal, and the crystals in fact to be principally pentagonal dodecahedrons.

It was thought that this substance might be foreign to the real constitution of the ash. The discovery, however, of a crystal with the lustre and appearance of pyrites imbedded deeply in the interior of a feldspar rendered it impossible to suppose this mineral to be merely blown up from local rocks, and so intermingled with

the ash. Remarkable deposits of it, having the appearance of infiltration along cleavage planes, occur occasionally in feldspar crystals.

Among the amorphous fragments, *Olivine* was not observed; many fragments picked up on suspicion being found to be easily soluble in hydrofluoric acid.

One of the most interesting features of this ash is the nature of the various *enclosures* in its principal minerals. They obviously give us a means of judging of their relative order of formation.

Classifying on this basis, *Magnetite* would come first in order of formation. It occurs as an inclusion in all the silicates present. It will be noticed protruding from the crystals of hypersthene in figures 3 and 4.

Pyrites might be of contemporary origin.

The *Pyroxenes* would in that case be second in order, for while including magnetite they are themselves included in the feldspars.

The *Feldspars* were probably the last minerals formed.

Vitreous inclusions are abundant, generally iron stained to a light-brown tint and enclosing the bubble which probably started their formation. Very often these inclusions are ranged parallel to the outline of the crystal; often again the vitreous mass has had the symmetrical form of the containing crystal impressed upon it. Sometimes then by their individual form, sometimes by their disposition, it is possible to judge of the former crystalline symmetry of a mere formless fragment containing such enclosures.

ADDITIONAL NOTES.

Subsequent to the reading of the foregoing, the author received many additional samples, both of the ash and of the block pumice. To the courtesy and kindness of Mr. T. Brewis the author owes these specimens in the first instance. Through information received from that gentleman samples were obtained from Captains who were in the neighbourhood of Krakatoa during the period of the eruption. To Captain Ralston, of the *Niobe*; Captain Calangich, of the *Jafet II.*; and, above all, to Captain Thomson, of the ship *Medea*, the author's best thanks are due.

The specimens of block pumice received bore, one and all, remains of marine life, incrusting the walls of the larger surface cells. Mineralogically they were not found to differ; many, however, showed veins or layers of black vesicular glass, giving a stratified appearance. The specimens, some of which are now in the Museum of Science and Art, Dublin, were picked up considerably to the south-west of the Straits of Sunda.

Dust from Batavia did not, on examination and comparison with that gathered at half that distance from Krakatoa, indicate any such sifting of its constituents in the course of its journey as M. Renard assumes in his Paper, read before the Académie Royale de Belgique (November 3, 1883). The probable explanation is that the dust was thrown so high, and in such quantities, that for many miles it was descending almost vertically, and was not, therefore, subjected to such a sifting process as it would have experienced had it been travelling horizontally.

Bearing on this point, the following computation respecting the height to which the dust, &c., was projected may be of interest:—

Captain W. Thomson heard the first explosion of Krakatoa at two o'clock on August the 26th. He was then in Lat. $5^{\circ} 56'$ S., Long. $106^{\circ} 31'$ E. Immediately after, and before the second explosion, which succeeded in ten minutes, a "black mass, rolling up, like smoke, in clouds was observed to the westward." It attained an altitude of about 12° ; and, as the *Medea* will be found to have been just seventy-six miles, as the crow flies, from Krakatoa, a height of about seventeen miles is obtained for the cloud.

At five o'clock the *Medea* came to an anchor in Lat. $5^{\circ} 58'$ S., Long. $106^{\circ} 46'$ E., 89.3 miles direct from Krakatoa. The dust cloud had meanwhile been going up suddenly with each explosion; and now, as Captain Thomson cast anchor, he read the angle of elevation of the cloud, it was 40° . Obviously the column had advanced towards him; but some idea of its approach may be gathered from his subsequent statement that "the wind during the whole of the eruption was W.S.W., force between 3 and 4." Taking its velocity as twenty-one miles per hour, its advance in the three hours since the first explosion would be sixty-three miles. On this assumption the altitude of the cloud would be twenty-one miles. Other observations from other points of view would be of interest.

Captain Thomson's narrative is one of much interest from the intelligence and care displayed in his observations, although made under trying circumstances.

He records "electrical displays" round the vast column of smoke (steam) ascending from Krakatoa on the evening of the 22nd of August. These took the form of vivid lightning, flashes darting from and around the column. Showers of sand and gravel on the 23rd. The terrific explosions of the 26th and 27th are described as "shaking the ship." He was then some eighty miles off, with an intervening screen of mountainous country.

With regard to the presence of *Pyrites* in the ash, nothing was said about it by M. Renard in his original Paper (which was not, however, known to the author of these notes at the time of preparing his communication to the Royal Dublin Society); but in a note appended to a Paper appearing in *Nature* (April 17th), as the joint production of that distinguished mineralogist and of Mr. Murray, its occurrence is mentioned and dismissed as "accidental." It is, however, not alone present, free, as aggregations of cubes and dodecahedrons, but also as an inclusion in the feldspars and in the hypersthene. Again, its abundant occurrence in the ash received from various localities is observable. Fifty specimens were counted by the author in one of three slides prepared from about half a gramme of the dust from Batavia. The dust had been treated for the removal of glass, feldspars, and free magnetite. It is hard to see why, under the circumstances, it should be considered accidental.

Hematite in thin, blood-red, semi-translucent flakes occurs in the ash. It is neither cleavable perceptibly, nor elastic, and is soluble in hydrochloric acid. It shows no trace of dichroism.

The very great abundance in the ash of *Hypersthene*, compared to *Augite*, suggests that the original rock should be considered more of the nature of a hypersthene andesite than an augite andesite. In connexion with this point the results of Mr. Whitman Cross' examination of a hypersthene andesite, kindly brought under the author's notice by Professor V. Ball, are of much interest. (Bulletin of the United States' Geological Survey, No. 1, 1883.)

NOTE ADDED IN THE PRESS.

M. C. Flammarion, in the *Revue d'Astronomie Populaire*, July, 1884, p. 265, estimates the probable height of projection of the dust, &c., from Krakatoa as at least 20,000 metres ($12\frac{1}{2}$ miles).

Observations made on board the *Elizabeth*, on the comparatively insignificant explosion of May the 20th, 1883, gave 11,000 metres as the height of projection on that occasion.

XXXIII.—ON AN ARGENTIFEROUS GALENETIC-BLENDE AT
OVOCA. BY C. R. C. TICHBORNE, LL. D., F. C. S., &c.

[Read, October 6, 1884.]

I AM strongly of opinion that we should never lose an opportunity of bringing before the scientific public any natural product of this country which is likely to become of commercial value. The general uncertainty which appertains to all mining operations appears aggravated in Ireland, where it almost seems as if we hung upon the fringe of extensive mineral deposits. The want of smelting materials adds greatly to our difficulties. In the year 1875 I had the honour of placing before this Society¹ a specimen of a rich magnetite found in Wicklow, which at that time was unknown to the Geological Survey. The veins of this ore could be traced for some two miles or more. Consignments of the magnetite were sent to Staffordshire to be smelted, and the most flattering account of the quality of the iron obtained therefrom was returned; yet I believe this ore lies *perdu*.

I wish, on the present occasion, to bring before the Society a description of another ore of even more importance. Of this ore very little is known, and I intend to offer some speculations upon its general character. I believe that the lode may be typical of many ores, which will be found disseminated in lead mines, but of these there is no record except a short reference in the Mineral Statistics² for the year 1882, and also a reference to which my attention has been drawn within the last week, and subsequent to my analysis and report upon this mineral, viz.:—a paragraph in a Paper entitled, “Notes on the Ancient and Recent Mining Operations in the East Ovoca District,” by P. H. Argall.³

The mineral I am now about to describe is known as “Blue-stone,” and locally in Wicklow as “Kilmacooite,” from the dis-

¹ Journal of the Royal Geological Society of Ireland, vol. iv., part 4.

² Mineral Statistics of the United Kingdom of Great Britain and Ireland, for the year 1882, pp. 88 and 94.

³ Scientific Proceedings, R. D. S., vol. iii., n. s., p. 225.

trict called Kilmacoo. It is so called in Mr. Argall's Paper. The mineral seemed to have been well known to Mr. G. H. Kinahan, whose intimate knowledge of the mineralogy of county Wicklow induced me to make inquiries of him. He gives as localities—the lode of the Magpie mine and the Connary mine, both in East Ovoca, with the Mona mine in Anglesey.

It is called "Bluestone" by the mining inspectors,¹ and it seems that about 1,240 tons of this or a similar ore are raised in the principality during the year.

The ore is a hard, steel-grey-coloured mineral, having something of the appearance of sulphide of antimony. If we except the colour, however, it does not resemble that mineral in any respect, for the structure is that of a fine-grained sacchorid mass. The ore is extremely hard, and it is broken with difficulty. In fact the rock has to be quarried by blasting. The pieces I have seen are very uniform in character, but are occasionally interspersed with crystals of pyrites and a hard, black, siliceous rock. A very slight examination will suffice to determine the fact that this mineral is a natural lode, and is not the result of an ancient working. This latter theory was once upon a time promulgated.

A piece weighed in the air 34·942 grammes : when weighed in water it gave 27·5655 grammes as the weight, so that the mineral has a specific gravity of 4·736. It will be observed that this gravity is somewhere intermediate between galena and blende. It is harder than either of those minerals. The ore, as found in Ovoca, seems, from the description given of the Welsh mineral, very much of the same character. But I have never seen a specimen from the Mona mine. As will be perceived further on, however it differs in general composition, it is much richer in silver than one of the varieties found in Wales. To quote from the Mineral Statistics, we are told that "Bluestone is an ore of zinc; average analysis—zinc, 32·15 per cent.; lead, 11·6, and $10\frac{3}{4}$ ounces of silver per ton, with a small percentage of iron and copper." But at page 88 in the same book we are informed that from the Mona mine, in Wales, they extract 5·535 ozs. from 514 tons, and that at the Morfa Du mine 5·082 ozs. from 726 tons, which represents re-

¹ Mineral Statistics of the United Kingdom of Great Britain and Ireland, for the year 1882, p. 5.

spectively $10\frac{3}{4}$ and 6·9 ozs. per ton. The following is the analysis of the argentiferous galenetic blende, so-called "Bluestone," as found at the Connary mine, E. Wicklow.

Silver, ¹	.	.	.	.	.	.	.	0·024
Zinc,	.	.	.	.	.	.	.	25·27
Lead,	.	.	.	.	.	.	.	25·18
Iron,	.	.	.	.	.	.	.	5·51
Manganese,	.	.	.	.	.	trace,		
Antimony,	.	.	.	.	.	.	.	0·21
Arsenic,	.	.	.	.	.	.	.	0·08
Copper,	.	.	.	.	.	.	.	2·50
Aluminum,	.	.	.	.	.	.	.	0·60
Magnesium, with traces of Calcium,	.	.	.	.	.	.	.	0·02
Sulphur,	.	.	.	.	.	.	.	23·71
Silica, &c.,	.	.	.	.	.	.	.	16·896
								100·000

This mineral may therefore be said to consist of

Sulphide of Zinc,	.	.	.	.	37·68	per cent.
Sulphide of Lead,	.	.	.	.	29·07	„
Sulphide of Silver,	.	.	.	.	00·275	„

and contains variable quantities of pyrites, which in this particular specimen amounts to 10 per cent.

The sulphide would represent nearly 22 per cent. of the sulphur found.

It was examined for the rarer metals by the spectroscope, but no indication of those elements could be got.

Gold was present in very small quantities. It was not estimated.

Mr. A. Ryder, of the Ovoca Mining Company, has kindly given me the following information upon the subject of the lie of the ore :—"The bluestone commences immediately to the east of a fault. It is here very rich in sulphur, and consequently of little value. We have driven on it for about 120 fathoms east, and have found that it increases in size (*i. e.* thickness of lode) and value as we go east. It also increases in value as we go deeper. It is the most 'bunchy' ore I know, growing in one place from 4 inches thick up to 3 feet 6 inches. In a distance of four fathoms I

¹ Equal to 8·6 ounces per ton (nearly 8 ounces troy).

calculate that there are about 1,000 tons in sight. The bluestone seems to be surrounded by coal, with veins of bluestone on the north, and on the south side blue slate, and white micaceous schist, and deeper down comes iron pyrites."

Of course, from a commercial point of view, the amount of silver found in this ore is the most important item of the analysis. Our analysis gives rather different results from those obtained in the Welsh mines, but they do not agree at all with the analyses given in the notes to Mr. Argall's Paper. Five analyses are given, and silver is only mentioned in three out of the five, which give respectively 5, $7\frac{1}{2}$, and 6 ounces per ton¹. From reasons which we shall shortly state, we think it probable that most of the samples must have been not only poor in silver but very indefinite samples of the bluestone. It may be interesting to compare this argentiferous ore with some others which are well known and worked for their silver. The following figures are taken from Dana's Mineralogy, 5th edition:—

Argentiferous Galena, Hartz,	. . .	.03 to .05 per cent.
English Galena,		.02 to .06 „
Lead Hills,		.03 to .06 „
American ores which are worked, run as		
low as		.001
Argentiferous ore from Ovoca,	. . .	.024

The last-named Ovoca ore compares very favourably with the above list, which includes some of our great sources of silver. If we examine this mineral with the naked eye, particles of pyrites may be seen scattered through the mass in an accidental and rather erratic manner. The remainder of the mineral is, however, remarkably homogeneous, and will bear examination under the microscope by reflected light with considerable impunity. The silver exists as sulphide, because dilute sulphuric acid does not dissolve any trace of that metal from the mineral.

The actual composition of this ore brings us to the consideration of two points, viz.:—(1) How far we should be justified in considering it as a distinct mineralogical specimen; (2) The construc-

¹ Since this Paper went to Press, samples of the ore have been assayed in London, giving as high as 9 ozs. of silver per ton, and also containing 1 dwt. of gold.

tion of the names it has received. I may as well state at once that, as regards the last point, I have a strong objection to the naming of minerals after places, particularly when named after small and unknown localities. Thus Dana has named a fine-grained mixture of galena and blende Huasolite, from the province of Huasco, where it was found. Even here, I am of opinion that such terms are not desirable, if we wish to inculcate the idea that they are distinct species. A province, however, is generally well known, and it is quite different to Kilmacoo—a local name, not even to be found in any published gazetteer or postal directory. The objection would be obvious, because until we got “Kilmacooite” recognized in the text-books upon mineralogy, the man of science would be at a loss to know what that name meant, or even to trace its connexions. There is also as great an objection to the term “Blue-stone,” the name used by the miners in Wales. The mineral is of a steel-grey colour, not blue; and, besides, this term is applied to a well-known chemical substance. I therefore prefer to call it argentiferous galenetic blende.

I view the mineral as an intimate mixture of fine crystals of galena and blende, which, although they form a fine-grained saccharid mass, apparently homogeneous to the eye, I have no hesitation in saying is composed of a mechanical mixture of microscopic crystals of two minerals. When treated with dilute nitric acid, the blende seems to be attacked first, but I do not attach much importance to this fact. If, however, we powder some of the mineral and examine it under the microscope with an inch object-glass, and strongly illuminate it with transmitted light alone, we find that about two-thirds of the particles transmit light, whilst the others do not. Now, galena owes its strong metallic lustre to its great opacity, and I think we are justified in pronouncing that these last particles are galena, and that those which transmit light are blende. The finest film of galena that can be got by acting upon an alkaline solution of lead oxide with thio-urea does not transmit light, whilst blende obtained artificially by a similar method is quite transparent.

I do not think the analysis in Mr. Argall's Paper could represent very pure specimens of the minerals. It will be observed that the samples procured by me are very uniform in character, except a few isolated crystals of pyrites, which can be perceived with the eye.

In the five analyses given in Mr. Argall's Paper there is a great discrepancy of composition; thus: the lead varies from $7\frac{1}{2}$ to 26 per cent.; the zinc from 8 to 49 per cent., and, where estimated, the silver respectively 4, 6, and $7\frac{1}{2}$ ozs. This great variation in composition is easily understood when we note the iron; for we find that one sample, marked "E," must have contained about 23 per cent. of pyrites; sample "A" 32 per cent., and sample "C" more than half pyrites.

The samples examined by me contained more silver than the highest estimation given in these analyses.

In concluding this short notice of this ore, I am tempted to quote from my report upon the Dublin International Exhibition of 1865.¹ In giving the statistics of the raising of silver in Ireland I stated that this county was a large supplier of the valuable metal, but I am afraid to make the calculation now which I did at that period. I then stated that Ireland produced 14,000 ounces of silver per annum, or 2·4 per cent. of the whole of the silver raised in the world, and its value might be estimated at £3,850 per annum, exclusive of the lead raised at the same time. If 1,000 tons of this argentiferous ore can be sighted, which represents of silver alone 8,000 ounces, how lamentable it seems that this valuable industrial resource should remain unworked—mere earth which might be transmuted into bone and sinew.

¹ *Chemical News*, July, 21, 1865: Report upon the Dublin Exhibition, and Official Report, by C. R. Tichborne.

XXXIV.—NOTES ON SOME OF THE IRISH CRYSTALLINE
IRON ORES. BY G. H. KINAHAN, M.R.I.A., &c.

[Read, April 21, 1884].

PART I.

A QUESTION that appears to attract some attention in America at the present time is “The Genesis of the Crystalline Iron Ores”; therefore some notes on the lodes and accumulations of these ores in Ireland may be of interest.

These ores, excluding the carbonates, occur in lodes and in interbedded masses, generally lenticular and irregular. Formerly they were extensively mined in Ireland; but after the last furnace was put out, about 230 years ago, and those operations had ceased, most of the pits and accompanying works were covered up, so that the sites of many of them are now unknown. A few, however, of these ancient works have of late years been re-opened, while in other places deposits have been discovered and worked, so that from these later workings we can learn something about the nature of the deposits now in question.

Such ores are due to the decomposition of organic matter and carbonic acid. Chalybeate water contains iron, either as the sulphate or as the carbonate. When iron exists as the sulphate it has been derived from the decomposition of pyrite in the rocks through which the water has percolated; the iron in solution is oxidized on exposure to the atmosphere, and a certain proportion of it is deposited. The source of the iron, besides the sulphides, may be lodes or such like accumulations, and also the leaching out of the iron colouring matter of the rocks and clays. Le Conte thus describes the reactions that accompany the decomposition of organic matter:—

“Decomposition of organic matter is a process of oxidation. In contact with peroxide of iron (ferric oxide) it deoxidizes and becomes reduced to *protoxide* (ferrous oxide). The acids, especially carbonic acid, produced by decomposition of the organic matter, then unite with the protoxide, forming carbonate of iron. The carbonate, being soluble in water containing excess of carbonic acid, is washed

out, leaving the soil or rocks decolourized, and the iron-charged waters come up as chalybeate springs. But the ferrous carbonate rapidly oxidizes again in the presence of air, by exchanging its carbonic acid for oxygen, and returns to its former condition of ferric oxide, and is deposited.”¹

On account of these reactions, deposits of ferric oxide are found about iron springs, along the streams that flow from them, and in low places where their waters are collected. This is what usually takes place, but not always; for if the iron water accumulates in the presence of an excess of organic matter, such as peat, all the iron cannot be reoxidized, but must remain in the form of ferrous carbonate.²

“Thus there are two forms in which iron leached out from the soils and rocks may accumulate, viz., ferric oxide and ferrous carbonate. The former is accumulated where the organic matter is in small quantities, and consumes itself in doing the work of dissolving and carrying the latter where the organic matter is in excess.”

The recent, or the more or less superficial, accumulations of iron ores may be first described. In some of the estuaries and lagoons earthy iron ore or some other ferriferous strata are deposited. In the estuary or lagoon of the Slaney (Wexford harbour) the muds are often ferriferous. In some places the ferriferous muds become richer toward the upper part, and are often covered by a thin seam or layer of ferric oxide, above which is mud. This arrangement would seem to suggest that the iron came down the Slaney, partly in solution and partly in suspension, it being supplied by the decomposition of the pyrite in the Cambro-silurian and Carboniferous argillaceous rocks and the leaching out of the colouring matter from them and the Cambrians. The lands of the “intakes” of other estuaries are often in part ferriferous, with seams or disseminated particles of iron ore in them.

It is principally during winter floods that the muds accumulate

¹ Other authorities ascribe it to a decomposition of the salt, the carbonic acid escaping, while water and oxygen take its place, thus forming a hydrous ferric oxide.

² At the bottom of some of the Irish bogs there is “stone turf,” more or less impregnated with some of the sulphate or carbonate of iron, or both combined. If only the latter is present when the turf is first cut, it is not iron-stained, but after it is dried it is found to be full of little particles of the ferric oxide, the turf becoming more or less “iron-marked.”

but it is during the summer heat, when the water is shallow, that the iron is deposited, partly by the ore being concentrated by evaporation, and partly by the chemical agencies already mentioned, which precipitate the soluble carbonate and sulphate, having more power to operate. For these reasons we should have first plain mud, then ferriferous muds with seams of ore, and then the same alternations repeated.

At times the iron-ore would be in excess, as whether the ore in solution be either the carbonate or the sulphate, when the waters are low and heated a quantity of the ferric oxide is deposited in the shallow pools and along the beds of the rivers and their tributaries, which stores are brought down by the first series of floods to be deposited in the estuaries or such like still waters.

The Ovoca river, county Wicklow, and such like rivers, which receive mine drainage, carry down in suspension and in solution a vast quantity of iron, to be afterwards deposited along the lower parts of their courses and in their estuaries and outside in deep water. Ferriferous river water also deposits iron in the lakes and loughauns through which it passes.

If, however, the loughauns and pools are shallow, the ore is generally washed out of them by the autumnal and winter floods. The stream that flows northward along the Maum valley, county Galway, gets quite thick and turbid during the summer heat, while a quantity of the ferric oxide is deposited in the pools, to be washed out of them and carried away by the subsequent floods.

It is a remarkable fact in connexion with the ores in the alluvium of the Irish rivers, that these old deposits are often of considerable thickness and extent, such not being the case with the recent ones. Those thick deposits are now nearly always covered with a greater or less thickness of alluvium. These peculiarities may possibly be due to the leaching out of the colouring matter of the rocks having been more active formerly; that matter having been removed to such a depth, the leaching now goes on very slowly.

Bog iron ores and ochres, although found in the alluvium of lakes and rivers, are very often associated with peat or peaty accumulations, and in general occupy hollows or nearly level surfaces; but not always, as some occur on hill slopes. When in hollows and on flats the overlying bog may be due to the iron ore having

formed an impervious floor, on which mosses, lichens, grass, heathers, &c., grow and decay. Such peat accumulations are necessarily thin, as the iron ore floor is not congenial to the rapid growth of bog.

At the present day the ore that is being formed at the surface is usually ochre, the bog iron ores being beneath greater or less thicknesses of surface accumulations. The latter is always more or less argillaceous, but in some places the surface is a rich granular ore of apparently a newer growth.

It may be observed in Ireland that where these ores occur associated with peat, the bog areas usually lie on more or less pyritous rocks, such as the black coal-measure shales, the calp shales, and black limestones, and the pyritous metamorphosed rocks; and these appear to have been in a great measure the source of the bog iron ore. This, however, is not always the case, as the iron garnets, the ferriferous micas, hornblendes, and pyroxenes, &c., in some rocks rapidly decompose, and are a considerable source of the ferric oxide; while in parts of Ulster there is a sub-metamorphosed sandstone, which, with its associated schistose rocks, supply extensive accumulations of ochre. These sandstones weather very rapidly, and in general to considerable depths—some, indeed, have all their cementing materials washed or leached out of them, leaving a residue of more or less pure sand. The normal colours of these sandstones seem to be different shades of green, or bluish-green; but these rapidly and deeply weather into a brownish iron-masked rock, with a thin dirty-white crust or surface. Besides the direct leaching of the soil or rocks, there are in places chalybeate springs which supply hydrous ferric oxide from more or less deep sources. The ochre forms a greater or less mound, or perhaps a sheet, round such springs; or may well up through boggy land, thus forming a ferriferous boggy swamp.

These bog iron ores and those allied to them, which have been briefly described, have accumulated at or near the surface. There are, however, in many of the rocks forming the surface, fissures, joints, cracks, and such like openings, into which portions of the iron in solution must flow to form deposits in cavities below the surface. Such seems to have been one of the sources in the case of the Antrim "pebble ore" described in the second part of this Paper; while in other places the leakage from younger strata seems

to have supplied the material for the iron ore now found in the underlying or older beds. Thus the iron ores in the Carboniferous limestone may have permeated downward during the formation of the Coal-measures; the Silurian iron ores during the formation of the Carboniferous rocks, &c., &c. Such a theory, however, will not account for all of the iron ore accumulations, as will appear from the brief descriptions given in the second part of some of the Irish lodes and other accumulations.

PART II.

In the first part of this Paper we drew attention to the iron ores in the surface accumulations, and their probable mode of formation; while in this it is proposed to refer more specially to the lodes, and such like, in the older rocks, accompanied with suggestions as to the possible sources from whence the iron may have come, beginning with the Tertiary *Iron Ore Measures* of the county of Antrim.

ANTRIM IRON MINES.

The Tertiary dolerites of the counties of Derry and Antrim, contain interbedded *Iron Ore Measures*. These appear to have been lacustrine deposits, which accumulated in shallow lakes or ponds of water, in hollows on ancient surfaces of the lava sheets, to be subsequently covered up by newer sheets of the dolerite. When fully developed the members of these measures are:—

1. Lithomarge, or laterite, with inliers of bole
2. Ochreous rock (Pavement).
3. Bole, or alumnious ore (*second ore*).
4. Pisolitic, or pebble ore (*first ore*).
5. Steatitic rock (Brushing).
6. Steatitic clay (Holing).
7. Alumite (or alum clay).
8. Lignite.

The lignite and alumite¹ occur only near the margins of the different basins, wholly, or in part, replacing the iron ores (3 and 4).

¹ Alumite is somewhat similar to the French clay called Bauxite, and is often so named.

No. 1. *Lithomarge*.—This is in part a methyloitic rock, as it is usually more or less steatitic. It probably consisted, at first, of muds formed from the weathering of the exposed surfaces of the dolerite, its constituents having been carried into the lakes by rain, rivulets, and wind. In it there are beds and lenticular masses of bole, sometimes rich enough to be worked as iron ore; the normal lithomarge representing the wash of continuous rains or the drift of continuous or heavy winds, while the beds of bole may be the wash after long periods of drought.¹ In the lithomarge are blocks of dolerite with the outer parts decomposed to a slight depth. As these may occur at some height above the base of the lithomarge, it is not very easy to account for their appearance. (See Pl. xvii., Scientific Proc., Roy. Dub. Soc., vol. iii., new series). This theory for the formation of the lithomarge will not be received without dispute. My son, Gerrard A. Kinahan, who has examined it very carefully, believes that it cannot be a sedimentary rock, but that it is evidently a methyloitic dolerite formed *in situ*. In favour of this theory he refers to the dolerite blocks in it, and the amygdaloidal portions; but apparently against this theory are the inlying beds and lentils of bole, with thin seams and bits of lignite—the amygdaloidal portions are at the surface of the underlying dolerite flow.

No. 2. *Ochreous Rock*.—This lies conformably on the lithomarge, forming its surface, and is called the pavement, because it is the floor of the iron ores. The surface of the pavement has been denuded. There seems to have been a break in the course of operations, as the measures above it were deposited under different conditions to those below it. Before, however, describing the *iron ores* (Nos. 3 and 4), we will turn our attention to the alumite and lignite.

Nos. 7 and 8. *Alumite and Lignite*.—These rocks, although placed uppermost in the list, seem to be older than the iron ores, having accumulated more or less contemporaneously with the lithomarge; they being littoral accumulating while the lithomarge was deposited in the deeper water. The alumite appears to have been originally lithomarge; but as the bog (now lignite) extended out over the

¹ As in some cases, the lignite was forming at the margin of the pools, while the lithomarge was accumulating in the deeper portions. It is probable that some of the iron ore in these boles had its origin in the leaching by the lignite of the colouring matter from the lithomarge, as seams and pieces occur in the bole, but not in the latter.

lithomarge, it leached the iron out of it, and left a residuum of alum clay; consequently the upper portions of the beds are richest, while in depth they graduate into lithomarge. At first lithomarge, alumite, and lignite gradually filled up the lakes; next, these accumulations were covered over by a flow or flows of dolerite, the steatitic rocks (Nos. 5 and 6) being the tuffose and decomposed underneath portion of the flow.

Nos. 3 and 4. *Bole* or *Alumnious Iron Ore* (2nd ore), and the *Pisolitic* or *Pebbly Ore* (1st ore).—We have next to consider how these ores accumulated between the lithomarge and dolerite. It would appear evident that they are younger than the overlying bed of dolerite, for the following reasons: first, coming up through the iron ore measures in the Glenariff mines, as mentioned by Mr. P. H. Argall,¹ there are nearly perpendicular dykes bearing about N. 15° W. These are thus described:—"These dykes may be divided into two distinct classes: first, those which stop at the roof, or *stop dykes*, and second, those that penetrate the roof, or *through dykes*; the latter invariably displace the ore measures, and bake the pisolitic seam, while the "stop dykes" neither displace nor bake the seam. The dykes that stop at the roof have a steatitic parting separating them from it, similar to that above the pisolitic ore."

Some of the "stop dykes" turn over or "splash" against the roof, which goes to prove that they are newer than it; while the "through dykes" in general can be traced up to the sheet of dolerite to which they belong. "As already stated, the pisolitic ore is neither baked nor displaced by the majority of the dykes which stop at the roof; while it is nearly always displaced and indurated by the dykes which penetrate the roof; from which it would appear that the pisolitic ore was formed prior to the latter and subsequent to the former."

The pisolitic ore has larger pisolites and is richer at the surface, the richness and size of the pisolites decreasing downward gradually, till it merges into the bole, which often is too poor to be profitably worked. The ore seam (Nos. 3 and 4) is of very irregular thickness, as in some places the roof descends until it rests on the "pavement,"

¹ Scient. Proc. R.D.S., vol. iii., new series. Mr. Argall, late resident agent of the Glenariff mines, has examined the iron ore measures very carefully, and from his notes we will quote frequently.

or there are hollows and pot-holes in the latter, or the pisolitic ore may be absent, the roof resting on the bole, or the latter may be absent.¹

From the facts that have been stated, it seems evident that the iron ore seam must be considerably younger than the overlying beds, and that it occupies a shrinkage fissure, this fissure being due, probably, to the drying and contraction of the lithomarge, the latter shrinking away from the steatic bottom of the dolerite; while toward the margins of the basins the lignite, in general, shrank away from the alumite, as between them a thin bed of iron ore occurs in places.² Into this fissure the iron ore, in part, as suggested by Mr. Argall, found its way in solution; but at the same time it was probably considerably augmented by the iron leached from the lithomarge during its change into alumite.

To me it would appear that the above is the most plausible way of accounting for the occurrence of the iron ore seam, as it lies unconformably on the "pavement," while the "stop dykes" are evidently younger than the latter, while they are older than the seam. It is also worthy of note that these "stop dykes" act very similarly to the cross courses, heaves, and the like, that cross a standing lode, as in such cases the seam is much thicker and richer at one side of the cross course than at the other. This thickening of a stranding vein at one side of cross courses has not, as yet, been satisfactorily explained; but probably it is due to a somewhat similar cause to that which thickens the horizontal Antrim lodes.

If the above theory as to the formation and growth of the horizontal iron lode is correct, it can easily be imagined how iron ores may have accumulated in other places. They may have come down in solution from the surface, or water may have leached rocks as it passed down through them, the ore subsequently being deposited in fissures and other vacancies.

Here we may draw attention to the gossan of the Ovoca mines,

¹ From a conversation with Walter Jameson, Esq., the resident director of the Eglintoun Chemical Company's Works, Glenarm, &c., I am led to believe that his theory as to the formation of the alumite and associate beds is very similar to, if not identical with, that given above.

² The late W. Jory Henwood, in his description of the Cornish and other mines, has satisfactorily proved that the "lay and lay," or horizontal interstratified lodes, occupy cavities due to the irregular vertical shrinkage of beds, or parts of beds.

county Wicklow (hereafter to be described), as it shrunk away from the underlying sulphur lode, forming a horizontal fissure, which in part remained open (if we except the water that was in it), while in part it was occupied by a "gossan lode." As the latter contained minerals not a trace of which has been found in the normal lode, they suggest that the gossan lode was filled from above by foreign minerals in solution: this "gossan lode," therefore, seems to have been filled somewhat similarly to the horizontal iron lodes of the county of Antrim. In the latter case the boggy water has leached the iron out of the dolerite; while, as mentioned by Argall, in places on the surface, where the bog water comes in contact with the dolerite, beds of bog iron ore are forming. It is worthy of note that where the "through dykes" cut the pisolitic, the latter is often changed into magnetite.

DYSERT AND DUNAMASE, QUEEN'S COUNTY, WITH KILCOLMAN
AND SHANAGOLDEN, COUNTY OF LIMERICK.

At these Queen's County and Limerick localities there are old mines and veins of limonite mixed with hematite. At Dysert there are the remains of old workings that cannot be properly examined. In one place the ore seems to be in a mass of "fault-rock," and in another in a cave; and in the first place hematite is interstratified with shale. At Dunamase there is an untried vein. At Kilcolman silicious limonite occurs in an irregular mass, while at Shanagolden it is in "fault-rock." In both counties the ores occur in the Upper Limestone, close below the base of the coal-measures. The production of the iron ore may possibly have been due to the decay of the pyrites in the overlying coal-measure shales; as from this sulphate of iron would be formed and an insoluble hydrated peroxide of iron—the first to pass off in solution, the latter remaining to form the mass of ore. Or the peroxide of iron may have accumulated in the limestone caves simultaneously with the deposition of the coal-measure shales, a part of the clay also being carried down to form the shales in the ore, a part of the iron present going to form the ore and another portion the pyrite; or both processes may have occurred in turn.

Some distance to the southward a cave was discovered in the Ashford limestone quarry. It is on the same geological horizon

as the ore at Kilcolman. It dips under the coal-measures, and when first opened it contained a thick deposit of slightly ferriferous cave earth. A chalybeate stream occupies it during part of the year; but as the water does not deposit any iron in the cave, the iron must be accumulating in some subterranean cavity, or the water must come to the surface a good distance away in a chalybeate spring.

COUNTIES OF CORK AND WATERFORD.

These counties were once famous for their iron mines; but although it is easy to find the sites of the forges and iron mills, the old workings are unknown, or cannot be examined in their present state. These mines seem to have been principally situated in the Yellow Sandstone ground, but some were in the Old Red Sandstone, and others in the Carboniferous Slate.

Some of the iron ores appeared to occur as the gossan back of copper lodes, but others have all the appearance of being independent lodes. At Glandore, county of Cork, there is a limonite back to a copper lode. This lode is remarkable, as the present "mineral channel" was first a brecciated "fault-rock," in which fissures opened that were filled by the copper lode; while, after the iron ore back had formed, a second system of fissure opened in the iron ore and the associated breccia, which are now occupied by manganese ores.

At the west end of Bear Island there is a standing lode of hematite, about eight feet wide, in the Carboniferous Slate; while elsewhere there are many smaller and usually irregular veins and strings of hematite, of the micaceous variety. These veins seem to be best developed in the areas where there are Intrusive Rocks.

As these veins occur below the black shales of the Carboniferous Slate group, it is possible that the ore may have had its genesis from the pyrites in them, or it may have welled up from below, it being in part the leaching of the underlying purple and red rocks of the Upper and Lower Old Red Sandstone.

It should be pointed out that there was a centre of vulcanicity in the neighbourhood of Berehaven during the accumulation of the Carboniferous Rocks, which probably had some kind of connexion with the development of the iron ore strings and veins. This action also seems to have had something to do with the accumulation of

the copper ores ; because at Allihies, near the whinstone intrusions the ore is concentrated in large lodes, while elsewhere in the county of Cork the ore is in more or less small and numerous veins, or disseminated in particles in the rocks of the Yellow Sandstone (Griffith) group.

COUNTIES OF WEXFORD AND WICKLOW.

In these counties, besides the old workings, of which very little is now known, there are the iron ore backs to the pyrite lodes of the Ovoca mines ; while in the purple and green Cambro-silurian slates there are irregular cakes or lentils and strings of iron ore.

Here the central member of the Cambro-silurians is made up of interstratifications of whinstones, felstones, tuffs, limestones, and schists, while above and below these there are the upper and lower red and purple slates. Many of the limestone and the calcareous schists are impregnated more or less with carbonate of iron, some, indeed, being poor iron ore (chalybite) ; while in the red and purple slate, but especially those of the upper zone, there are cakes or lentils of limonite and strings of hematite.

The cakes of limonite are of irregular shapes, and are probably due to chalybeate springs that welled up while the clays were accumulating ; their source being in the underlying ferriferous limestone ; while the strings of hematite seem to be connected with vulcanicity, being due to steam that penetrated the cracks and joints, leaching the colouring matter out of the adjoining portion of the slates. In favour of the latter suggestion we find in other places, near intrusions of irruptive rocks, that similar strings of hematite are developed ; while the newer granite (Carboniferous) causes the adjacent rocks to be "iron-masked."

At the Ovoca mines, between Ballycapple to the N.E. and Knockmohill to the S.W., the gossan backs to the lodes are, in general, ochre or limonite ; while in places, but especially near heaves, the latter may be associated more or less with manganese, chalybite, and magnetite. The limonite was deposited in horizontal courses ; but afterwards, when drying, it shrank away from the normal lodes, leaving vacancies, some of which remained open as large vugs, while others were filled with the "gossan lodes" already described. It is remarkable that the rocks adjoining the main mineral channel are "iron-masked" (ochreized), similar to the rocks

adjoining the intrusions of the Carboniferous (?) granite; which may indicate that these outbursts and the lode are of similar age.

Descriptions of other places in Ireland where these iron ores were worked would be little more than repetitions of what has already been said, as we could only mention of the county of Clare, that there were formerly extensive mines there; some, such as those of Ballymalone and Bealkelly, being on cakes of ore, like those in the county of Wexford—Cambro-silurians; and of the counties of Longford, Roscommon, Fermanagh and Tyrone, that the iron-workings there are in the Carboniferous Limestone, &c., &c.; that the old workings are now inaccessible, while the new lodes have not been sufficiently investigated to afford much information. We may, however, mention that at Knocksnaghty, county of Clare, and in other places, graphite, associated with iron, occurs in true veins.

XXXV.—NOTES ON THE EARTHQUAKE THAT TOOK PLACE
IN ESSEX ON THE MORNING OF APRIL 22,
1884. BY G. H. KINAHAN, M.R.I.A., &c.

[Read, June 16, 1884.]

DESCRIPTIONS of this earthquake have already appeared in the various daily papers and the scientific journals, but there are certain phenomena connected with it that as yet have not been described, and the principal object of this communication is to draw attention to such.

The disturbances in the area of structural damage took place between 9.15 and 9.20 a.m., April 22nd, the damaged structures being nearly all found in a tract southward of Colchester. From this tract, as a centre, the shock seems to have been felt for nearly equal distances in the surrounding country; northward it is recorded in the valley of the Humber; N.-W. at Liverpool, and westward as far as Bristol. To the S. and E. its conspicuous limits were the sea coast, but slight shocks are said to have been felt east of the Straits of Dover, at Ostend and Boulogne.

The tracts in which the maximum damage was done are five in number and more or less isolated; they, in the order of intensity, are as follows:—1, Wivenhoe; 2, Peldon; 3, Abberton and Langenhoe; 4, Colchester; and 5, West Mersea; all except the first being north of the estuary of the Blackwater, and west of that of the Colne. Associated with these centres there are marginal tracts in which much damage occurred, but less than in the maximum areas, while in the adjoining county more or less damage was done at isolated places as follows:—South of the Blackwater, in the vicinity of Bradwell, and at Tillingham; to the westward at Bishop (N.-W. of Maldon), Witham, Braintree, Stisted, Coggeshall, and Oldham; to the north at Nayland; to the north-eastward at Bromley Hall, Ardleigh, Dedham, and Manningtree; while eastward, toward the Naze, although it was felt, no damage seems to have been recorded.

Before proceeding further with the descriptions of the areas, it is expedient to give brief descriptions of the building materials used in this portion of Essex, and peculiarity of the structures that

seem to have assisted in their destruction, beginning with the materials, which may be generally divided up as follows:—1st, brick; 2nd, stone; 3rd, lath and plaster; and 4th, sheiling or wood.

1. *Brick Buildings.*—Some of these are what are called “frame houses,” being bricks in wooden frames; but they are not common in the affected area, and none of those remarked appeared to be damaged. The other brick structures suffered severely, especially chimneys. The old houses in general have more traces of the quake than the new, but not always, as in North Wivenhoe both were nearly equally injured. The styles of the brick buildings seem to facilitate their coming down. Low structures have often long thin chimneys plastered against higher ones, without any binding or clamps, many of which fell down, doing considerable damage. In other places the tall houses are without gables, the chimneys coming up through a high, sloped roof, which necessitated their being of a greater or less height, and many of these came down, if square, or if their greatest width was transverse to the direction of the shock; if we may judge by what can be seen outside the limits of the affected areas, many of the mouths of the chimneys, which were built of single bricks, were cracked and belled at their mouths from the heat in the flues, and consequently easily came down. Many of the walls that came down were two bricks in thickness, they having been run up without binding the outside ones to those inside; while the regularly built and bonded walls stood in all cases; also the mortar used in building seems to have been of a very poor quality. Many of the cracks in these structures are in connexion with opes, such as windows and doorways: some, however, are quite independent of them. The most interesting cracks are those in the chimneys, especially where the tops of the latter are partially turned round.

2. *Stone Structures.*—The major portion of these only occur in the church towers, and in some cases are much older than the associated churches. Some of these old towers suffered severely, which cannot be much wondered at. Take as an example the Langenhoe tower, which was old, rotten, and cobbled; and here the major portion of the damage was due mostly to its fall, but not solely, as the cracks through the wall of the nave and porches are due to the earthquake. At Peldon, however, the damage was mostly due

to the quake; for, although the tower in part fell, the chancel—which is said not to be more than forty years old—is considerably injured. Old roofs, such as that on Little Wigborough, lost their tiles. In Colchester a portion of the spire of the Congregational church came down. This, however, was not very remarkable, as the portion severed from it was a patch that had been added on account of damages from a storm.

3 and 4. *Lath and Plaster and "Sheilings," or Wooden Houses.*—These are varieties of "frame houses." In the first the frames are lathed and then plastered, while in the latter the frames are covered with thin wooden slabs or slats. As these classes of houses can vibrate, especially the second, they suffered very little, except some very old ones, from which the plaster or slabs were shaken down; many of them, however, had stacks of brick chimneys that fell and did considerable damage.

GEOLOGY OF THE AREAS OF STRUCTURAL DESTRUCTION.

From the geological map by my colleague, Mr. W. H. Dalton, we learn that their different areas are on, or at the margin of, exposures of the London clay, while rarely has any damage occurred on the younger accumulations. The destruction on it, however, is confined to more or less small limited defined tracts. In connexion with the geology, it may be mentioned that the evidence would seem to suggest that the shock does not appear to have travelled from one of the intensely affected areas to another, but that it was in action in all at one and the same time, travelling in each in more or less different directions, which, as pointed out by Dr. Taylor, of Ipswich, seem to be due to the diversion of the shock by lines of faults or breaks in the continuity of the strata.

Wivenhoe.—This lies immediately N.E. of a part of the estuary of the Colne, the intense shock having affected a very small tract which is margined to the southward by the break of the Colne river valley (N. 75° W.); and adjoining this line the shock was very severe, while it gradually decreased in intensity towards the N.E., as a mile to the N.E. the houses in the north portion of the village of Wivenhoe Cross were not injured. Eastward, in the Alresford district, the damage was very slight compared to that at Wivenhoe; also to the west of the water at Rowhedge, although in

the northern portion of the latter a good number of houses were more or less wrecked. It is worthy of note that the railway cutting appears to have modified the shock, as the houses adjoining it, both to the south and north, scarcely suffered. Here, as previously mentioned, the new houses were wrecked as much as the old, especially those near the Hall, to the north of the railway.

The most ruined portion of this village is on the narrow outcrop of London clay at the margin of the glacial drift, but at the same time all the other structures that were injured are on the latter, and some of these received considerable damage.

The shock evidently came from the N.N.E., but when it met the break of the Colne river valley it seems to have recoiled, or in part collided along it, thus causing additional destruction in the vicinity of the river. The narrow band of London clay also appears to have had some sort of connexion with the maximum damage done, as in places it appears to have travelled in it under the younger accumulations. This is also suggested farther northward, as between Colchester and Ardleigh there are narrow tongues of London clay, the houses on which were injured while those on the newer gravel were not, except in one instance.

PELDON, ABBERTON, AND LANGENHOE DISTRICT.

In this locality the structural damages occurred in a rather considerable-sized N.E. and S.W. tract, between the marches of the Mersea and Pyfleet creeks on the S.E. and the valley of the Lagen river on the N.W., and extending from Fingrinhoe on the N.E. to Virley on the S.W. To the N.E., at Hornwood, the damages were slight, although it is close to both Wivenhoe and Rowhedge, but divided from them respectively by the breaks of the Colne and Roman rivers valleys; while to the S.W. the destructive action gradually decreases until eventually it died out before Tolleshunt Knight was reached. At Virley the action is interesting, as this village is only separated from Salcot by a small narrow E. and W. creek, yet the houses in Virley, most of them comparatively new, are damaged; while those in Salcot, which are old and frail, were not affected—all this tract, except a small portion near Fingrinhoe, is on the London clay. To the southward of Virley, in a line running about E. S. E. by E. from Tolles-

hunt Darcy, a little damage was done, the injured structures being on the margin of the London clay.

Peldon, Area of excessive Damage.—This extends W. N. W. by W., and E. S. E. by E., being bounded northward and southward by small stream valleys, the maximum damages having taken place at the southern and western margins. In this area the effects would appear to suggest that the shock had a sort of rotary motion; the main direction, however, seems to have been southward, and the concussion against the lines that form the southern and western boundaries appear to have caused the great destruction in those places. The twist in the direction of the shock in the vicinity of the southern boundary is exemplified by the twist in the chimney of Strood mill, and in the damages that have been described as happening to Dr. Green's house in the same vicinity. A well near Peldon is said to have become quite muddy.

Abberton and Langenhoe Area of excessive Damages.—This tract extends about N. N. E. and S. S. W., its southern boundary being the small stream valley that bounds the Peldon area on the northward. The maximum damage seems to have happened in the vicinity of Abberton, where the well is said to have remained muddy for a few days. The shock appears to have been rotary, but the general direction would seem to have been from the southeastward, having concussion shocks from the boundaries, which might account for the rotary appearance and the twisted action observed at Langenhoe, where the church and glebe house suffered considerably.

To the N. E., at Fingrinhoe and Frenchman's Lane, the structural damages margin the tract of glacial drift previously referred to.

Colchester Area.—The maximum damage occurred in a narrow nearly east and west strip along the south Roman wall, from Head Gate to the valley of the Colne. South of this strip very little damage was done, while northward it rapidly decreased, scarcely any damage occurring north of the Colne river. From the geological map by Mr. Dalton we learn that a narrow outcrop of London clay occurs along the south wall, widening a little towards the eastward, the excessive damage following this widening. North of this outcrop the damaged structures are on the glacial drift, while on the alluvium at East Bridge there are some

houses wrecked, although to the southward, at Hythe Bridge, houses similarly situated are uninjured.¹ The houses at East Bridge are remarkable, because the direction of the shock seems to have turned southwestward at the river, while elsewhere in Colchester it seems to have gone nearly N. (N.N.E. by N.). The water in the artesian well that supplies Colchester rose, after the quake, seven feet, which height it has still kept up. This possibly is due to the earthquake rupturing a dyke, or even a thin parting of "fault-rock," and thereby adding an additional area of chalk to that from which the water was previously drawn.

Scarcely any damage was done in the western portion and suburb of Colchester, while southward to the valley of the Roman river the isolated houses, &c., damaged, nearly invariably are on small tongues of London clay, the principal exceptions being at Roman Hill, Middlewick, and Cockwort. East of the Colne river valley, as elsewhere when the boundary or break of an excessively damaged area is passed, very little damage occurs, the greatest being in the village of Greensted and Wivenhoe Park. These damaged are on London clay, as also most of them to the N.E. along the Crockleford stream valley.

West Mersea Area.—This portion of the island of Mersea seems to have been given more importance than it is entitled to, on account of the cracks that opened in it and the springs that came up, while in reality the damage done was less than that in the country to the northward; also it was altogether confined to a small tract. To the S.W. of the island along the sea road, near a slight drift escarpment to the N. and N.W. of SS. Peter and Paul's Well, an E. and W. crack opened. It is said to have been wide enough to put in your open hand and to have been over two yards deep. In appearance it was very like the cracks not uncommon near the escarpments of drift cliffs. The well is at the base of the cliff, at the margin of the alluvial flat, and has remarkably clear water, which is said to have risen and become quite muddy, while a similar phenomenon took place in the pump well of the Coastguard Station, a little to the north. To the N. E. of this, at Crossfarm, a second E. and W. crack is said to have opened, while in two places along it water spouted up—at one

¹ Some houses on the alluvium at Wivenhoe are injured.

discoloured with red sand, and at the other with yellow. These springs are said by the tenant to have lasted for about half an hour. About thirty-two paces to the north of this line the water in a well rose two feet and became quite muddy. All the people from whom inquiries were made agreed in saying that the waters in these different places had no peculiar taste or smell.

The shock seems to have come from the N.N.E., and was described by a boatman coming north across the Blackwater estuary, as having first taken the stern of his boat as if he had run on a mud bank, and then nearly twisted the rudder out of his hand, as if he had cleared the bank. This statement of the boatman as to the direction of the shock was confirmed by the Chief Boatman in charge of the Coastguard Station and others.

Of the exact time at which the shock was felt at each place nothing satisfactory could be learned, as outside Colchester very few people could say their clocks were right; in each village, and often in the one house, there being fifteen minutes or more between the times registered by the clocks. The bearings of the walls on which those that stopped hung, indicate directions.

The cracks in the walls are also very unsatisfactory, as those in one building may dip in different directions or even be at right angles to one another; thus between Peldon and Strood Mill the majority bear nearly E. and W. (W.N.W. by W.), and dip northward at 40° ; but some of these dip southward while those of another system run nearly N. and S., and dip eastward at 30° ; also in the Abberton and Langenhoe area they are most irregular, both as to direction and dip. At Colchester in general the cracks bear nearly E. and W., but some do not; most of them have a more or less high angle of dip, and at Wivenhoe the greater number are parallel to the river bed (N.N.W. and S.S.E.). The cracks in general are from $\frac{1}{4}$ to $\frac{1}{2}$ an inch wide, but in a few places, such as in the Peldon area, they are wider. In no place could I find a trace of the walls having moved up and down along the cracks.

The inhabitants of the different areas of greatest structural damage appear to have been so scared that they cannot tell if there was more than one shock. At the following places, however, two or more shocks are said to have been felt:—Mark Tay, 2; Maldon, 3; Walton-on-the-Naze, 2; Ipswich, 3 (where it is also

said a shock was felt at 11.8 p.m.) ; Sudbury, 2 ; and Colchester, 2 or 3.

In the Peldon area, it is stated by Dr. Green of Croagh and the people of the village of Peldon, that a slight quake was felt about six or eight weeks before April 22.

SUMMARY.

The area of structural damage was limited, but in the country surrounding it the shock was felt for considerable distances.

In the area of structural damages there were smaller areas in which the effects were greatest. These smaller areas are distinctly margined at two or more sides by well-marked lines, while at one or two of these lines the maximum damage in each occurred. The greatest damage was done in the Peldon and Abberton areas.

In the areas of greatest effect, the shock travelled in different directions ; yet, in all, the shock appears to have occurred at the same moment.

The geological formations in the area of structural damage are "London clay," "glacial drift," and "alluvium." In two places, Eastbridge, Colchester, and at Wivenhoe, damages were observed on the latter, while from the north portion of Wivenhoe to Alresford, and in the northern part of Colchester, damages occur on the glacial drift ; but elsewhere all damages, especially the greater ones, are found on the London clay ; while nearly invariably the destruction ceased at the margin of the younger accumulation.

XXXVI.—ON THE BOTANY OF THE RIVER SUIR. BY H. C.
HART, B. A.

[Read, May 21, 1883.]

THE river Suir takes its rise in the northern flanks of the Devil's Bit Mountain (1583 feet), in the northern part of the county Tipperary. Through this county it runs in a southerly direction to Newcastle, on the north of the Knockmealdown Mountains, at the borders of Tipperary and Waterford. From this point, running at first north to Clonmel and then east to the Waterford estuary, it is the southern boundary of Tipperary and Kilkenny and the northern of Waterford. The estuary may be said to terminate at the junction of the Suir and Barrow, about six miles below Waterford. From this point the tide, however, reaches upwards to a mile and a-half above Carrick, a distance of about twenty-eight miles. From its source to the Barrow junction the Suir is about 120 miles in length. I did not examine the stream below Carrick, which is nineteen miles above the Barrow junction. From Carrick the river is tidal and the banks disagreeable for pedestrianism, while the botany is, I believe, fairly well known.

Accompanied by a friend, and with average good weather, this tour was very agreeable. The scenery is in many places extremely pretty, chiefly near the source, about Golden Bridge, and from that to Clonmel through Caher. In some places, as at Knocklofty, there is magnificent timber along the banks, while numerous ruined castles, abbeys, and mills are met with in the most picturesque situations. We spent one day on the Devil's Bit, and having found on its north side what we believed to be the Suir, we started off with a gay disregard of compass bearings along the source of an eastern tributary of the Shannon. At dusk we found out our mistake, and made our retreat good to Templemore. The following morning, however, we got fairly to work, and kept the banks to Carrick in four days and a-half. In a journey of this kind the variety and abundance of difficulties to be overcome is the chief source of enjoyment. Deep ditches, often crossed with the help of an overhanging tree—tributaries, which had to be

swam—treacherous swamps, sometimes decoying us to islands—and numerous swims, sometimes intentional, sometimes otherwise, kept up the excitement. On two occasions only had we to leave the immediate banks of the river, which was high during our visit—once was for about half a-mile, near Templemore at Loughlin Bridge, and the other detour was rendered necessary about eight or ten miles below Thurles, where a large tract of low land was completely inundated.

Several rare species were met with. Perhaps the most interesting was *Eriophorum latifolium*, which was gathered in one place abundantly. New localities and the frequency of some scarce plants in unrecorded situations showed that this river had been little searched. Many kinds of aquatic birds inhabit the larger swamps mentioned above, especially that of Loughmore and the river is well worthy of further exploration in this direction.

I will give an account of my tour from day to day, and at the close give a separate enumeration of the rarest specimens observed. The river lies from the source to below Loughmore in District 7, and from thence to Carrick in District 2 of the Cybele Hibernica.

On the 29th of May, 1882, having left Dublin by an early train and breakfasted at Templemore, we made our way through Sir John Carden's demesne to the Devil's Bit. On old walls at the Priory *Saxifraga tridactylites* and *Draba verna* were plentiful—two species which are frequently seen in company also on sea-side sandhills. In low meadows westward *Orchis morio* and *Listera ovata* were observed.

On the Devil's Bit the following observations were made on the altitude of plants above sea level :—

AT 1500 FEET (DEVIL'S BIT).

Cotyledon umbilicus.

Carex pilulifera.

AT 1400 FEET (KILDUFF).

Ulex europæus.

Callitriche verna.

Lycopodium clavatum.

AT 1300 FEET (DEVIL'S BIT).

Ajuga reptans.

AT 1150 FEET (DEVIL'S BIT).

Myosotis versicolor.

AT 1100 FEET (DEVIL'S BIT).

Listera ovata.

AT 1050 FEET (DEVIL'S BIT)

Bunium flexuosum.

Ophioglossum vulgatum.

These are above the usual vertical limits of several of the species. The adders-tongue is remarkably abundant on the western slopes of the Devil's Bit. Nothing else of interest was noticed along these hills to the northern extremity of the chain. During the detour already mentioned, along a stream which proved to be a tributary of the Brosna, flowing west to the Shannon, I met with *Geum rivale*, *Alchemilla vulgaris*, *Sambucus ebulus*, *Crepis paludosa*, *Antennaria dioica*, *Humulus lupulus*, *Carex remota*, *C. sylvatica*, *Equisetum maximum*, and *E. sylvaticum*.

The following day, May 30, having driven to Borrisnoe, as far as the roads would permit, we crossed country and fell in with the stream on the eastern slope of Benduff. On the upland pasture ground I noticed *Carduus pratensis*, *Rubus idæus*, *Lathyrus macrorrhizus*, *Habenaria viridis*, and *Polystichum angulare*. The river flows between high and wide clayey banks at its source, and soon settles down into a winding, rocky, sandstone bed, amongst copses and bluffs of oak, sallow, mountain ash, blackthorn, and other shrubby vegetation. For a couple of miles here the stream is rapid and very pretty, and hedges are numerous, *Carex pilulifera*, *C. hirta*, *C. acuta*, and *C. remota*. with the commoner sorts being noted. Valerian and the graceful water avens (*Geum rivale*) also decorate the banks. In this part of its course the river is much frequented by water ouzels. Young and old were continually flitting across our path. Near Skehanagh bridge I gathered *Lycopus europæus*, *Juncus glaucus*, *Carex ovalis*, and *C. paniculata*. At Killough bridge *Humulus lupulus* has established itself, and here also *Equisetum maximum* was observed. Soon after this bridge the river Suir, which has hitherto been flowing eastward, turns south, and runs a straight and apparently artificial course between hedgerows through rich flat lowlands in a slow and uninteresting manner. Along here *Barbarea vulgaris* is very frequent, with commoner grasses, water mint, the larger forget-me-not, and yellow iris. Between Knockane bridge and the railway, where the Suir comes inside District 2, *Epilobium hirsutum*, *Myriophyllum alterniflorum*, *Potamogeton natans*, *P. crispus*, *Carex paniculata*, *C. vesicaria*, *C. riparia*, and *Juncus glaucus* were met with.

Several of the species enumerated up to this are additions to the flora of District 7. At this point the Great Southern and Western Railway is the boundary, and the remainder of my explo-

rations lie in District 2. The river and railway are nearly parallel for several miles, and several tributaries have considerably increased the former. *Scirpus lacustris* first appears now, and *Carex vesicaria*, a local plant, has become common. Another local species, *Ænanthe phellandrium*, afterwards common and characteristic of the Suir, first shows itself at Cloon bridge by a small stream flowing into the Suir. In its company was *Ranunculus heterophyllus*, var. *floribundus*. After Cloon bridge *Ænanthe* is abundant; the early fresh green leaves, with their floating lace-work pattern, are very beautiful objects. *Carex acuta* occurs here too, and *Nuphar lutea* in a few places. Other larger water plants appear, as *Hippuris vulgaris*, *Alisma plantago*, *Veronica anagallis*, *V. beccabunga*, and *Equisetum limosum*. *Caltha palustris* is not common, and *Eupatorium cannabinum* very scarce. Here the country was much flooded, and the river often undistinguishable from the surrounding swamps; this was in the neighbourhood of Loughmore. *Nymphaea alba* and *Polygonum amphibium* are very plentiful. *Lysimachia vulgaris* was met with also—a plant confined to the banks of the larger lakes and rivers. Here the river makes a loop to the westward, and the banks being quite unapproachable for about half a mile, a detour was unavoidable. In the hedgerows I noticed *Viburnum opulus*, *Acer campestre* and *Rosa arvensis*. Again resuming our walk, or rather flounder, along the side of the channel, I noticed *Ranunculus lingua* and *Armoracia amphibia*, both—especially the former—local in Ireland. Both may be seen close to Thurles, which we were now approaching. *Carex vesicaria* is very frequent near Thurles also. We had been for some time travelling in an element which is usually traversed with boats, and we were not sorry that nightfall and Thurles came together with a cessation of labour. The intermediate stage in a river—that between a swift upland stream and a deep and certain lowland channel—is often the worst to deal with, as if it was for a time uncertain what its destination was eventually to be. In the latter part of this day's walk many birds at their breeding haunts enlivened our interests. Sedge warblers, redshanks, wild duck, teal, black-headed gulls, and other commoner birds, as well as perhaps some rarer ones, inhabit these swamps. This pursuit could not be studied without some time spent in boating.

On the following morning we made an early start from Thurles.

I should mention that we have so far followed the right or west bank of the river. South of Thurles the last three mentioned plants and *Ænanthe phellandrium* are still frequent. Between Thurles and Turtulla Mill I noticed *Menyanthes trifoliata*, *Potamogeton perfoliatus*, *P. lucens*, and *Carex riparia*. At the Mill the large water millfoil, *Myriophyllum verticillatum*, a rare plant in Ireland, was observed; and between that and Holycross I gathered *Ranunculus lingua*, *Solanum dulcamara*, *Alliaria officinalis*, and *Orchis morio*. These occurred at intervals along the river to Twoford bridge, and along here tributaries and heavy dykes rendered our journey very laborious, and we crossed to the left or east bank. We found willows overhanging these ditches often very serviceable; and even if the bough did give way and capsize the leader into the water, he was probably most of the way across at any rate. We had, however, determined, to cross all obstacles, so that a swim more or less was not important, and up to this the width of the water to be crossed was trifling. About two or three miles below Twoford bridge the river takes a wide bend westwards, and here there is a deep and impenetrable swamp. It was on the margin of this swamp I gathered *Eriophorum latifolium*, a very scarce plant in Ireland, and there appeared to be abundance of it. The marsh may be distinguished by the name of Aughakilleen. In the same marsh also I noticed *Pedicularis palustris*, *Carduus pratensis*, *Eupatorium cannabinum*, *Pinguicula vulgaris*, *Schoenus nigricans*, and *Carex vesicaria*. In some places the latter was so abundant that as sheets of its leaves moved in the wind in the light of a low sun, the effect was that of a meadow of shining golden yellow, while as a contrast the glaucous foliage of *Carex ampullacea* gleamed along the flooded fields like silver. On the higher land above this marsh *Orchis morio* is frequent, and again lower down about Camus bridge. Here also occurred *Nasturtium palustre*, *Lysimachia vulgaris*, and *Thalictrum flavum*; and near Castle Lake corn-mill I gathered *Potamogeton pusillus*. On this part of the river's banks to Golden, *Carex disticha* is frequent. In rich meadow ground on the east bank, a mile or two above Golden, I gathered *Bromus commutatus*, a rare grass in Ireland. It seemed native in this locality. At Golden, an exquisitely situated hamlet on the river, we obtained snug, clean, and primitive hospitality from two captivating old ladies, in a picturesque lodge, occasionally used by anglers. The news that Golden

possessed no hotel at first had filled us with dismay, but we soon found ourselves far better off than in an average Irish village inn.

On the 1st of June we made an early start from Golden. Altogether the scenery is delightful. Castles, abbeys, and other picturesque remains of the past abound. A more melancholy feature is the number of recently-abandoned handsome dwelling-places. Richly wooded and diversified scenery, amongst fertile hills and valleys brought us merrily along for the first few miles on firm banks on the west side of the river. The most interesting feature in the botany here was *Orchis morio*. It was very abundant, and of many hues and great luxuriance. I picked several pure white-flowered plants, and one really well-marked variety with the upper petals and sepals very dark and the lip nearly white—sweet and very large—of it and the white variety I procured bulbs. About Golden I noticed *Rubus idæus*, *Saxifraga tridactylites*, and *Ononis arvensis*. After a few miles we found it necessary to cross the river, which was now about sixty yards wide, with a strong current. Practical experience taught us that this is a little beyond the limit of distance which one can swim, holding his clothes dry overhead in one hand. The result of this painful experiment was that our clothes were mostly soaked for the remainder of the day. During the distance between Suir Castle and Cloughabready I noticed *Thalictrum flavum*, *Ænanthe phellandrium*, *Sparganium minimum*, and *Potamogeton perfoliatus*. The banks are now usually high and firm, the course of the river is more decided, and neighbouring swamps are fewer. The result of this is that the larger plants are scarcer, and many do not re-appear. On the right or west bank of the river, near Cloughabready Mill, I gathered *Carex paludosa* and *Scirpus sylvaticus*. The latter is very rare in the south of Ireland, and scarce in Ireland generally. It was a great pleasure to find a new locality for one of the handsomest of our native plants. I met with it again further on, near Cahir. I noticed *Nymphæa alba*, *Hippuris vulgaris*, *Ænanthe phellandrium*, and *Juncus glaucus*, a long way inland for the last-mentioned species.

The following morning, June 3, we left Cahir, and followed the right bank of the river through the beautiful demesne of Lady Margaret Chartreuse. Here first I met with *Scrophularia aquatica*,

afterwards becoming abundant. A little below Cahir the following also occur:—*Thalictrum flavum*, *Nasturtium palustre*, *Ænanthe phellandrium*, *Æ. crocata*, the latter becoming frequent soon, and *Tussilago petasites*. Near the end of the demesne I found *Carex acuta* abundant. Here, too, is a wild-looking patch of *Senecio saracenicus*, but I believe it is unquestionably an introduced plant in Ireland. After a few miles we approached Ardfinan, *Orchis morio* and *Thalictrum flavum* still accompanying us. In the village of Ardfinan *Senebiera didyma* has established itself, and in the stream *Sparganium simplex* was observed. About a mile lower down I met with *Scirpus sylvaticus* again; and all the way on to Clonmel *Thalictrum flavum*, *Nasturtium palustre*, *Scrophularia aquatica*, and the two *Ænanthes* are frequent and characteristic. About three miles below Ardfinan, near St. Bridget's Well, I gathered *Senecio saracenicus* for the second time, and on the opposite side of the river *Humulus lupulus* is, at any rate, thoroughly established. A little below Newcastle *Symphytum officinale* was first met with, and about three miles further on *Lotus major* was also observed. At Knocklofty and in Kilmanahan wood the timber is magnificent and well worth a visit, the ash-trees and a species of poplar (*P. monilifera*) being the finest I have ever seen. These are by the river, which we crossed here to the left bank. Since Newcastle the Suir has doubled back northwards in its course for several miles to the present point, whence it flows east through Clonmel to the sea at Waterford. Here many large shade-loving and aquatic plants abound; amongst them I gathered *Carex strigosa*, a very rare sedge in Ireland. I had found it previously, I believe, near Cahir. In the rank soil beneath this large timber *Ænanthe crocata* reached a height of above seven feet, and *Helosciadium nodiflorum* rivalled it with six feet of erect growth and radical leaves about three feet long in the largest plants. These will, I think, be recognised as extraordinary dimensions. Here were found also *Alliaria officinalis*, *Epilobium hirsutum*, *Valeriana officinalis*, *Crepis paludosa*, *Dipsacus sylvestris*, *Filago germanica*, and *Carex sylvatica*. *Peucedanum ostruthium* was noticed, too, apparently established amongst ground that had previously formed a road. In a couple more miles we reached Clonmel, where we remained for the night.

Next morning, June 4, we kept the towpath on the left or

north side of the river till we reached Carrick, and at the same time the limit of tidal effects. The river had quite lost its charms. For many miles the Galtee, Commeragh, and Knockmealdown Mountains had been at one point or another conspicuously beautiful against the skyline, while the immediate banks of the river were in several places lovely beyond description. But we had turned our backs on these charms, and descended to a richer and uglier plain, and to a badly macadamized towpath. So that we made all speed to Waterford, and hurried home by an afternoon train to Dublin. At Clonmel *Senebiera didyma*, *Solidago virgaurea*, *Carduus pycnocephalus*, two *Scrophularias*, and two *Ænanthes* occurred. From Clonmel downwards sedges have almost entirely disappeared. *Scrophularia aquatica* is very abundant, and so also is *Nasturtium palustre*. With the latter I found *N. sylvestre* also, a known locality for this plant, which is only found elsewhere in Ireland in one place on the Blackwater. Near Clonmel *Hypericum anglicum* grows, looking quite wild, on the river banks. It is, of course, not native in Ireland. From Kilsheelan bridge the proximity of the sea is soon felt. Cormorants begin to be plentiful, and near Carrick *Zostera marina* makes its appearance, accompanied by maritime sedges.

In conclusion, I will enumerate the species which may be added to the lists for District 7 and District 2 of the Cybele Hibernica, and some others whose range has been extended:—

DISTRICT 7.

Lycopus europæus, Linn.
Myriophyllum alterniflorum, D. C.
Juncus glaucus, Ehrh.
Carex remota, Linn.
C. ovalis, Good.
C. acuta, Linn.
C. pilulifera, Linn.
C. vesicaria, Linn.
C. riparia, Linn.
Lycopodium clavatum, Linn.
Equisetum maximum Linn.

DISTRICT 2.

Orchis morio, Linn.
Potamogeton lucens, Linn.
Eriophorum latifolium, Hoppe.
Carex acuta, Linn.
C. strigosa, Hud.
C. paludosa, Good.

The following less common plants, though previously recorded from the district in which I found them, were discovered in new localities:—

Thalictrum flavum, Linn.

Ranunculus lingua, Linn.

Nasturtium palustre, De Cand.

Senebiera didyma, Pers.

Armoracia amphibia, Koch.

Myriophyllum verticillatum, Linn.

Ænanthe phellandrium, Lamk.

Senecio saracenicus, Linn.

Lysimachia vulgaris, Linn.

Scrophularia aquatica, Linn.

Scirpus sylvaticus, Linn.

Carex vesicaria, Linn.

C. riparia, Linn.

Bromus commutatus, Schrod.

XXXVII.—ON VOLATILIZATION OF ZINC FROM GERMAN-SILVER ALLOYS. BY A. R. HASLAM.

[Read, November 17, 1884.]

HAVING read some time ago a Paper, in which it was stated by the writer that in the manufacture of German silver and brass considerable loss is sustained by the zinc becoming vaporized during the melting and cooling of the alloy, it occurred to me that the subject was deserving of further investigation, and accordingly the following somewhat interesting experiments were undertaken by me, first, to find the rate at which the zinc is vaporized by heat; and secondly, what action the other constituents, copper and nickel, exert on this vaporization. Three specimens of commercial German silver were obtained, having the following per centage composition:—

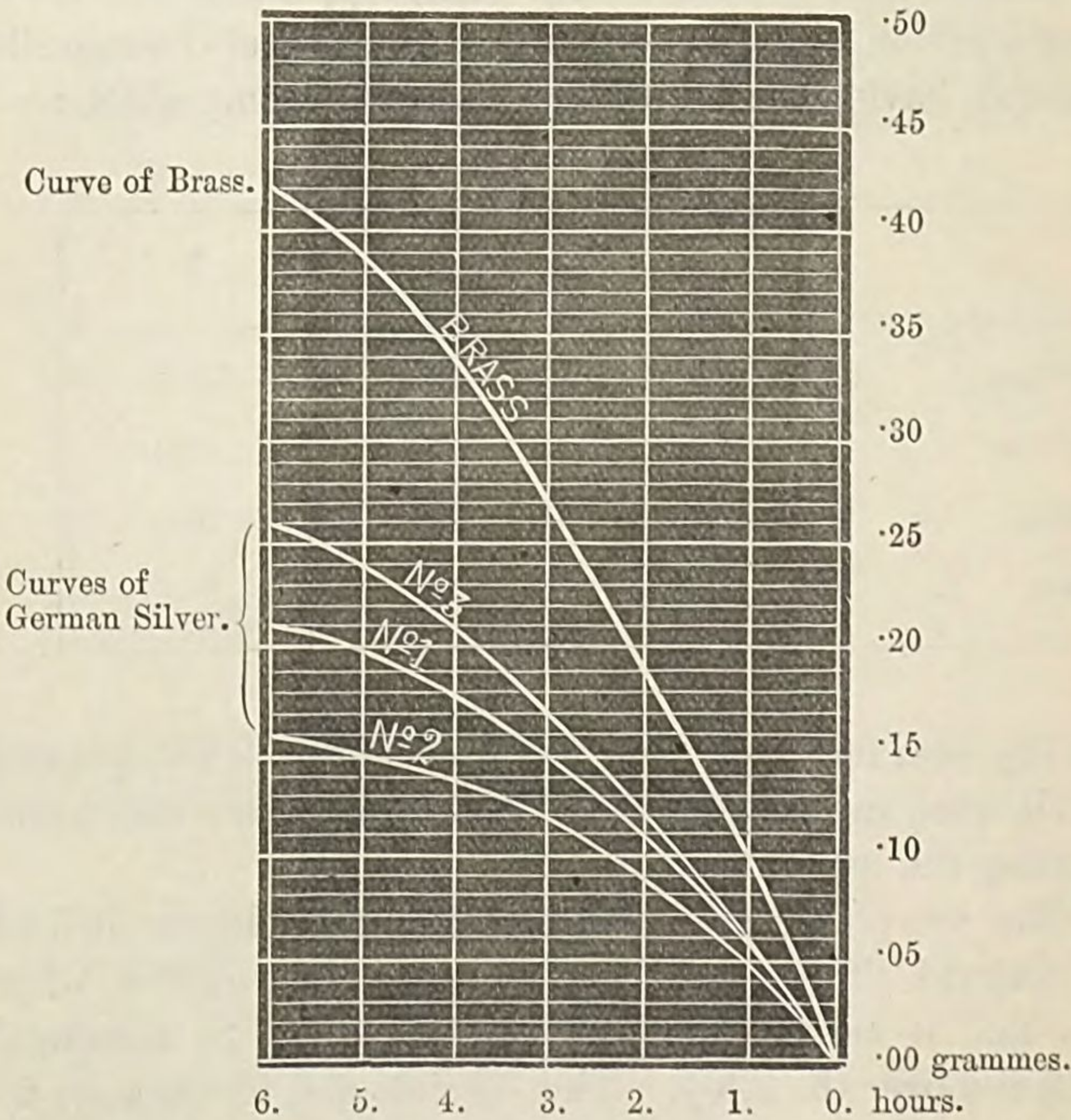
	1.	2.	3.
Copper, . . .	53·5	50·4	56·3
Nickel, . . .	14·3	17·6	11·4
Zinc, . . .	31·8	31·2	31·9
Iron, . . .	trace.		

The quantity used for experiment was in each case 2·258 grammes, and the following method was found both convenient and suitable for estimating the loss of the zinc.

The alloy was placed in a small porcelain crucible provided with a close-fitting lid, through which passed two tubes, likewise of porcelain, so that a current of dry hydrogen could be transmitted through it, and over the alloy. The crucible and its contents were then heated to bright redness in a Bunsen flame, and the alloy weighed from time to time, to ascertain the loss consequent on the evaporation of the zinc. The following table gives the results:—

Hours.	1. Loss per Hour in grammes.	2. Loss per Hour in grammes.	3. Loss per Hour in grammes.
1	·056	·050	·058
2	·052	·044	·056
3	·045	·034	·050
4	·038	·024	·044
5	·026	·016	·037
6	·016	·014	·029
Total loss	·233	·182	·274

It will at once be noticed, on looking at the above table, that



Curves showing the Volatilization of Zinc from German Silver Alloys.

the greatest amount of loss occurs in every case during the first

hour of experiment. After this there is a steady decrease in the amount of zinc vaporized from the alloy. In one experiment the alloy was heated for twelve hours, and it was found that the loss sustained in the last hour only amounted to .004 grammes.

The action of the other constituent, nickel, of the alloy is very striking. It will be observed that No. 2 alloy contains the most nickel and the least copper, and that the vaporization of the zinc proceeds more slowly in it than in the other alloys, while No. 3 contains the least nickel and most copper, and is dissociated much quicker. A specimen of brass of the same weight containing 30.6 per cent. of zinc when heated for the same time gave a total loss of .424 grammes, or nearly double that of the German silver containing the least nickel. The curves showing graphically this action of the nickel are shown in the figure.

From these carefully obtained results I am led to conclude that German silver appears to have much more the character of a perfect alloy than brass, and that the tendency of zinc to volatilize from German silver is determined by the quantity of nickel present in the alloy, the nickel increasing the affinity of the zinc. Might not therefore more nickel and less copper be used with advantage in the manufacture of this important alloy?

NOTE ADDED IN THE PRESS.

[Since this Paper was read I have made some further experiments on an alloy of nickel and zinc, having as near as possible the composition NiZn_2 . On heating this alloy, it was found that in six hours it had lost .122 grammes, or .060 less than the German silver alloy containing the most nickel. It was also found impossible at a bright-red heat to expel all the zinc from this alloy, 9 per cent. remaining constant, while in the case of brass, the percentage of zinc may be reduced as low as 1 per cent. I have not found it possible to deprive brass entirely of its zinc by heating it in a porcelain tube over a combustion furnace: from .6 to 1 per cent. remains constant.]

XXXVIII.—NOTE ON DUST REPULSION. By GEORGE
FRANCIS FITZGERALD, A.M., F.T.C.D.

[Read, June 5, 1884.]

DR. OLIVER J. LODGE has pointed out that when a body is warmer than dusty air in its neighbourhood, the dust has a tendency not to settle on it. When speaking to him on the subject he did not seem to have been aware of Prof. O. Reynolds' experiments on the motion of silk fibres suspended in air and subject to radiation,¹ which Professor O. Reynolds explains by the absorption of the radiations by the silk, and the consequent polarization of the air, warmed by contact with the small fibres, producing an apparent repulsion of the fibre. Professor O. Reynolds' theory of the radiometer points to the conclusion that very small bodies would act in dense air in the same way as the comparatively large vanes of a radiometer do in rare air. This application of Professor O. Reynolds' theory to explain the tendency of the warmth of a body to prevent dust settling on it seemed very obvious, and occurred to me immediately I heard of the experiments of Dr. Lodge, and I would not have thought it worth while mentioning only that I found that Dr. Lodge himself did not seem to have noticed it.

¹ Phil. Trans. R. S., 1879, part ii. On Certain Dimensional Properties of Matter in the Gaseous State.

XXXIX.—ON CURRENTS OF GAS IN THE VORTEX ATOM
THEORY OF GASES. BY GEORGE FRANCIS
FITZGERALD, A.M., F.T.C.D.

[Read, June 5, 1884.]

MR. J. J. THOMSON, in his book on Vortex Atoms, has called particular attention to the fact that the momentum of a vortex ring being proportional to its area, and its velocity through the medium getting less the greater its momentum, the velocity of hot simple vortex atoms is less than that of cold ones. Professor Osborne Reynolds, in his review in *Nature*, December 27th, 1883, of Mr. J. J. Thomson's book, called attention to the discrepancy that exists between this result and the fact that the velocity of sound is greater in hot than in cold gas. Now, on considering how the velocity of sound in a gas composed of vortex rings would be propagated, it is at once evident that the usual equations of motion do not apply to a system of atoms whose momentum is not proportional to their velocity, and this at once raises the question, What is the momentum of a current of vortex atoms? The answer to this of course depends on what the nature of a current of gas formed of vortex atoms is supposed to be. If it be supposed to be a current of the medium carrying the vortices with it, and if it be further supposed that the amount of medium carrying a given mass of vortices is independent of their size, then the momentum of the current will be, as we know it is, independent of the temperature of the gas. These assumptions, however, seem quite at variance with Mr. J. J. Thomson's investigation as to the relative velocity of hot and cold vortex atoms, where he assumes that each vortex atom moves, independently of the rest, through a medium at rest, and carries its momentum with it, and that the general effect is simply the superposition of the effects due to these independent vortices. The assumption as to the nature of a current of gas, that is consistent with this method of treating the subject, is the usual assumption that a current of gas consists in the motions of the molecules being so polarized that there are a greater number of molecules moving in the direction of the current at any one time than in any other direction, *but that*

the molecules are moving individually independently, and in the same manner as they do in a gas at rest. For instance, if a region in which there were many vortex atoms were in communication with one in which there were only a few, the vortex atoms would diffuse in a current out of the former into the latter. Now the momentum of this current for a given number of vortex atoms transferred per second across unit area would depend on the momentum of each vortex atom, and as this momentum is not proportional to the velocity of the atom, and is a function of its temperature, it is evident that the momentum of such a current would be a function of its temperature.

The whole notion that atoms are vortex rings in a medium raises serious difficulties as to the amount by which this medium is carried along by the motion of the earth, for instance, and by solid bodies enclosing masses of gas. If the earth does not carry the medium with it, the vortex atoms in the air must be so energetic as to be moving at nineteen miles a second through it, and their size and momentum must vary considerably from day to night, as they are going so much more rapidly at night than by day. Similarly the momentum of an enclosed mass of gas would vary with its temperature, if moving the enclosure only moves the enclosed vortices. On the other hand, if the earth does carry the medium with it, what withstands the centrifugal force of this revolving medium? Why does it not originate an enormous vortex? This and similar difficulties seem to point to the conclusion that to suppose atoms to be simple ring vortices in a perfect liquid can hardly be an adequate theory. There seems very good reason for believing that the hypothesis that the medium is simply a perfect liquid is hardly sufficient. It certainly is not sufficient to explain luminous and electrical and magnetic phenomena, to suppose the ether to be simply a perfect liquid at rest; and though it is too much to say that it will not ultimately be found a sufficient foundation for a theory of matter and material phenomena, at present, at least, there seems very little prospect of anybody's inventing how it ought to be moving, in order to have the known properties of the ether; and even the ingenious attempt to explain matter as due to simple ring vortices in it seems too simple to be adequate.

XL.—ON A METHOD OF STUDYING TRANSIENT CURRENTS
BY MEANS OF AN ELECTRODYNAMOMETER. BY
GEORGE FRANCIS FITZGERALD, A.M., F.T.C.D.

[Read June 7, 1884.]

WHEN a current of short duration, compared with the period of free vibration of a galvanometer needle, is passed through the galvanometer, the total quantity of the current is proportional to the sine of half the angle of swing of the needle. The swing produced is independent of the distribution of intensity of the current during its passage.

Now, if a similar transient current be passed through an electro-dynamometer, we have the following equation for the motion of the suspended coil while a current C is passing:—

$$I \cdot \frac{d^2\theta}{dt^2} = K \cdot C^2,$$

where I is the moment of inertia of the coil and K a constant.

Hence
$$\left. \frac{d\theta}{dt} \right|_0 = \frac{K}{I} \int C^2 dt$$

gives the angular velocity with which the needle begins to swing. If the suspension be bifilar during its free swing the motion is given by the equation

$$I \frac{d^2\theta}{dt^2} = -k \cdot \sin \theta,$$

where k is a constant depending on the method of suspension, &c. Hence, for the maximum swing,

$$\left. \frac{d\theta}{dt} \right| = 2 \sqrt{\frac{k}{I}} \cdot \sin \frac{1}{2} \theta.$$

Comparing this with the other value, we obtain

$$\int C^2 dt = \frac{2 \sqrt{Ik}}{K} \cdot \sin \frac{1}{2} \theta.$$

Now the value of $\int C^2 dt$ depends upon how the current varies during its period of transit, and if we can form any hypothesis as

to the law of its variation, we can calculate the period it took to pass, and its maximum electromotive force by comparing this result with that given by an ordinary ballistic galvanometer.

For instance, the secondary current at any time in Ruhmkorff's coil may, to a first approximation at least, be represented by an equation

$$C = C_0 \sin \pi \frac{t}{T},$$

where C_0 is the maximum current, and T the whole time of flow. The total current as given by the ballistic galvanometer is

$$Q = \int C dt = C_0 \int_0^T \sin \pi \frac{t}{T} dt = \frac{2TC_0}{\pi} C_0 T = \frac{1}{2} \pi Q.$$

The quantity given by the electro-dynamometer is

$$S = \int C^2 dt = C_0^2 \int_0^T \sin^2 \pi \frac{t}{T} dt = \frac{1}{2} C_0^2 T;$$

therefore
$$T = \frac{\pi^2 Q^2}{8S} \text{ and } C_0 = \frac{4S}{\pi Q}.$$

It is thus easy to see that the comparison of these observations would give a great deal of information about transient currents.

XLI.—ON A NON-SPARKING DYNAMO. BY GEORGE
FRANCIS FITZGERALD, A.M., F.T.C.D.

[Read, June 9, 1884.]

WHAT are called unipolar dynamos have no sudden change in the nature of the sliding contact, which is essential in all dynamos, and are consequently non-sparking. The arrangement I am about to describe is somewhat different, and is an application to a dynamo of the principle that Maxwell applied to Sir William Thomson's electric doubler (Maxwell's *Electricity and Magnetism*, vol. i., p. 298, s. 213) in order to prevent sparks in it, and which he likened to the regenerator in a heat engine.

Consider a series of coils arranged to rotate in a magnetic field as a gramme ring, but with their wires unconnected with one another, each coil being connected with a separate commutator and pair of brushes, and half the brushes being connected with one electrode, and the other half with the other. In this case the current would in general go through a number of the coils in parallel circuit. Now it is evident that by a suitable arrangement of the magnetic field and of the positions of the brushes on the commutator, it could be arranged that the break of contact of the brushes and commutator should take place when the current in the coil was zero. This is evident, because if the brushes made contact throughout a whole revolution, as in an alternating current dynamo, the current would be reversed every half revolution; and if the instant of reversal were the instant of break of contact, this would happen when no current was passing in the coils. It is not possible to arrange this unless there are at least two parallel coils carrying the current, as otherwise the whole current would be fluctuating, and might as well be alternating. With a number of coils parallel, it would evidently be quite possible to arrange that the time of break of contact of each pair of brushes and its commutator should occur when no current was running in the corresponding coil. One way of doing this would be, as in Maxwell's electric doubler, to arrange a subsidiary magnet system to alter the magnetic field

until the desired effect was produced. In any arrangement, with a number of coils in parallel circuit, it would be necessary to be particular as to the arrangement of the magnetic field, for fear of the currents being reversed in some of the coils. This would evidently waste a good deal of energy in heating the coils. In the proposed arrangement the energy of self-induction usually wasted in sparks would be spent in keeping the current running in the line, and there is reason to expect that such a dynamo would not exhibit the apparent increase of resistance with speed pointed out by Messrs. Ayrton and Perry.

XLII.—ON PHOTOMETERS MADE OF SOLID PARAFFIN, OR
OTHER TRANSLUCENT SUBSTANCE. BY J. JOLY,
B.E., Assistant to the Professor of Civil Engineering,
University of Dublin.

[Read, December 15, 1884.]

WHEN light enters a translucent body, such as paraffin, milk-glass, common opal, &c., it behaves as if scattered within the substance by numerous reflections—as if such bodies were not homogeneous, but consisted of particles differing in physical properties, in so far that some of them are opaque, others transparent, or as if some partial molecular symmetry led to the existence of planes of superior density within the substance. Such a substance as milk-glass would be an example of the first class of bodies; paraffin possibly of the second, or partly of both.

If now a prism be cut from a translucent body, and so exposed to a source of light that one only of its faces be illuminated, the light diffused through the substance and reflected out through the unilluminated faces of the prism gives it an appearance as if lighted up internally. The effect, in fact, is as if the prism itself was a source of light. Two such prisms laid together on smooth faces, and receiving light from separate sources (placed so as to be at opposite sides of the plane of division), appear as if each was emitting light proportional in intensity to the source of its supply. The double prism has the appearance of two luminous bodies laid side by side. When, however, the supply to each prism is brought to equality, they appear as if emitting equal quantities of light. In fact, it is hard to detect any longer that *two* prisms are being observed, so completely does all trace of the plane of division disappear.

The photometer I wish to bring to your notice consists of two prisms of paraffin, parallelepipeds in form, each about $2\frac{1}{2}'' \times 1'' \times \frac{1}{2}''$, sharply cut to the same dimensions, and laid together in their $2\frac{1}{2}'' \times 1''$ faces. In this position they are retained by two brass rings, such as are used for mounting objects for the microscope, melted on at each end.

The two sources of light to be compared are arranged at oppo-

site sides of the plane of division, and the combined prisms shifted till the intensity of the light received at opposite sides of the divisional plane is brought to equality—till, in fact, the prisms lie in an equally illuminated field. In this position the discontinuous appearance of the prisms vanishes, and they look like one continuous block of paraffin. While, however, this complete disappearance of the divisional line takes place when the sources of light are emitting rays of like colour, in general comparison is not between such, and a certain amount of judgment is required to determine when the two differently tinted luminous bodies are emitting equal quantities of light. This objection applies to all photometers of visual comparison: in this form the difficulty is much lessened by watching solely for the least conspicuous appearance of the line as the prisms are shifted. Tinted glasses to cut off these rays not common to both sources of light can, of course, be used.

It is found that more sensitive measurements are obtained from this form of photometer than from Bunsen's; the operation of adjustment also is less fatiguing, and is more rapidly effected. The sensitiveness of the arrangement is still further increased by interposing a silver leaf between the prisms, thus stopping all passage of light from one prism to the other. The addition of a lens for observing the divisional line adds to the facility and ease of adjusting. In this form, suitably mounted and protected from accidental sources of light, it will be found that the least movement from its position of equilibrium is noticeable. This extreme sensitiveness and ease of working is due to the very close juxtaposition of the luminous surfaces undergoing comparison. In Bunsen's photometer the surfaces compared are seen at some inches removed from each other.

Experiments have been made with alabaster, and with a highly translucent marble known as Mexican agate. These substances, however, proved inferior to paraffin. Good results would probably be obtained from milk-glass.

It is to be noted that if the prisms be not quite similar in translucency (they should be cut from the same piece of paraffin), it will be necessary to take two readings, with the faces of the combined prisms reversed in position respecting the lights, the mean of the two readings being taken as correct.

XLIII. — NOTES ON THE APATITE OF BUCKINGHAM,
OTTAWA COUNTY. BY G. H. KINAHAN, M.R.I.A.

[Read, December 15, 1884.]

THE apatite appears to be diffused very like galenite in limestone. It occurs in regular lodes, that is, veins with both foot and hanging walls; in irregular veins, that is, having only one wall; in string veins running irregularly through the rocks; as "lay in lay" on in veins between the stratification; in bunches; and I suspect in pipe veins: of the last, however, I am not quite certain.

According to the miners, it is always associated with a metamorphosed basic igneous rock, that the Canadians call "Pyroxene rock" [but that I would class among Macculloch's "Hornblende rocks," having more amphibole in them than diallage], and quartzites. The "Pyroxene rock" seems always to be present, and in general the quartzite, but not always.

What I saw of the apatite reminded me very much of the limestones and dolomytes that occur in the Irish Cambro-Silurians associated with igneous rocks [eurites (basic felstones) and gabbro], as these Cambro-Silurian limestones and dolomytes, or their petrological equivalents, ophytes, steatytes, and such like, occur tangled up with these igneous rocks, usually being more or less in bunches or lenticular masses, and sending string veins into the igneous rocks, or occurring as detached pieces or concretions in them, while nearly always there are also quartzites associated with them. Where our rocks are greatly metamorphosed, as in West Galway and other places, the eurites and gabbro have become rocks similar to those in the Buckingham township.

It has therefore occurred to me that it is possible, if not probable, that the apatite has replaced limestone or one of the allied rocks by chemical change or methylosis, as called by Dr. W. King, of Galway.

In favour of such a supposition, we find in the large bunches of apatite portions that merge into pure limestone, while in other places the rock will be in part apatite and in part limestone; also the bunches and irregular string veins remind one very much of

their limestone equivalents in the Irish Cambro-Silurian eurites; while the "lay and lay" are like the "shells of limestone" that are not uncommon in the county Donegal Cambro-Silurians—an apatite vein or a limestone vein with only one wall "makes" exactly similar. I could not satisfactorily find out if, in any place in the regular lodes, the apatite changed entirely into calcite [I was too weak and giddy after my recent illness to go down all the different shafts and deep workings]; but in one of the lodes which I saw under ground there was evidently calcite in places associated with the apatite.

When the apatite of the bunches is associated with limestone, the apatite in part is in crystals, from one inch or less to a foot or more in diameter. The largest crystal that has been got was found in the Emerald mine, just before I visited it, and weighed 800 lbs.; other accessories, such as crystals of black and white mica, amphibole, &c., &c., occur more frequently in the bunches than in the other accumulations of apatite.

In the Chelsea district (the vale of the Gatineau), nearer Ottawa, where the rocks are not as highly metamorphosed as in the Vale of the Du Lievre (Buckingham township), there are eurites and gabbros associated with limestones and dolomytes; but I could not find apatite, unless one specimen (which as yet I have not been able to get analysed) should turn out to be it: I suspect, however, it is not so.

NOTE ADDED IN THE PRESS.

On examination, the rock in question was found to contain a small percentage of apatite.

XLIV.—CANADIAN ARCHÆAN, OR PRE-CAMBRIAN ROCKS ;
WITH A COMPARISON WITH SOME OF THE IRISH
METAMORPHIC ROCKS. BY G. HENRY KINAHAN,
M.R.I.A., &c.

[Read, December 15, 1884.]

THIS Paper can only give a more or less general sketch of the subject in hand, as the time I had to spend in Canada was very limited; but at the same time the opportunities for examining the rocks were considerable. I would specially mention that the observations made, and the conclusions come to, were all personal; as, prior to visiting the different places and drawing my own conclusions, I was unacquainted with the opinions of the various writers on the subject, having read none of the literature connected therewith, except Logan's Report many years ago. I must, however, allow that, as the readers of my Papers in connexion with the supposed Archæan rocks in Ireland are aware, I have no faith in merely lithological characters, or in the boundaries and divisions founded solely on them: this circumstance may be supposed in part to have more or less prejudiced my judgment. But as my matured conclusions agree, as I find, in a great measure with those of Logan and Selwyn, they may perhaps be worthy of record. The title of this Paper is, perhaps, too presumptuous, as more properly it is a review of the Irish highly metamorphic rocks, and a comparison between them and some of the Canadian Archæan or Pre-Cambrian rocks. As introductory to the subject of the Paper, I beg to submit some observations on foliation, or the structure induced by metamorphism; and some other phenomena connected therewith, the examples being nearly entirely confined to Ireland, where this action has been more minutely studied.

Students of petrology and lithology seem now in general to believe in three classes of metamorphism, namely, Regional and

Contact, for which I have proposed respectively the terms *Metapepsis* and *Paroptesis* (see "Geology of Ireland," p. 175), and Chemical change, called by King, of Galway, *Methylosis*, while for a molecular change the American authorities use the term *Paramorphosis*. At the present time it is not intended to refer to the rocks of the latter classes, as these preliminary remarks refer specially to the others.

Paroptesis, or Contact metamorphism, must necessarily occur at a different time from Metapepsis or Regional metamorphism, in one and the same area; and the former may have taken place before or after the latter; or possibly there may have been two or more periods during which one or other of the actions may have been in force—thus, for instance, in a region there may have been first, in places, Paroptesis, which was succeeded by Metapepsis; while subsequently, in places, there was a newer Paroptesic action, or newer Metapepsis. The present state of metamorphism of some of these older Canadian rocks would seem to suggest that they had been subjected to a succession of alterations due to both of these kinds of metamorphism.

The S. E. of Ireland is an instructive area; as on both sides of the granite protrusion of the Leinster range there are bands of Paroptesic rocks. Those to the westward of the granite ridge have not been again altered (except some hereafter to be mentioned), while those eastward of the ridge have all experienced a second change, due to Metapepsis, which invades nearly all the Lower Palæozoic rocks of these portions of the counties of Dublin, Wicklow, and Wexford.

Thus, *as a general rule*, to the westward of the granite ridge there is a band of "baked" rocks, due to Paroptesis; while eastward of the ridge there is a band of typical gneiss and schist [due, first, to Paroptesis, and subsequently to Metapepsis], outside which are more or less metamorphic rocks [due to the subsequent metapepsis]. The metapepsic action seems to have been most intense in certain oblique westerly and easterly lines, so that if we traverse the region from north to south we will alternately pass over metamorphic and sub-metamorphic rocks; that is if we ignore a subsequent action now to be mentioned.

In this region, besides the intrusions of the normal Leinster granite (Cambro-Silurian age?), there were also newer intrusions

(Devonio-Silurian¹), which were accompanied by Paroptesis; so that in connexion with them we find the rocks more altered, the "baked" rocks in the band to the westward of the ridge having been changed into schists; while in places to the eastward the metamorphism has been intensified.

A fact which seems to be important is, that in connexion with the interstratified igneous Cambro-Silurian rocks there are the granitic roots (*laccoliths* of Gilbert), and in connexion with these, from the appearance of the adjacent rocks, there seems to have been Paroptesis; this, however, can only be conjectured, as the more recent Metapepsis has more or less obliterated it. Still, however, it should be kept in mind, as it shows how many stages of metamorphism rocks may have gone through.

There is also in this region a peculiarity still to be mentioned in the metamorphism. Years ago, in reference to the rocks of Dublin and Wicklow, Jukes pointed out that the younger, or Cambro-Silurian rocks were more altered than the older, or Cambrians. This, if I remember rightly, he suggested, was more apparent than real, as only the Cambro-Silurian in contact are exposed. But down S. E., in the county of Wexford, away from the granite ridge, the same thing occurs; as, nearly always, along the boundary between the Cambrians and Cambro-Silurians the latter are more altered than the former.² In the county Wicklow, to the north-west and westward of Rathdrum, there are rocks that Jukes put in the altered Cambro-Silurians, while Wyley would put them in the Cambrians, as has been mentioned elsewhere. I believe Wyley is right, they being intensely altered Cambrians, Jukes including them among the Cambro-Silurians on account of his having proved elsewhere that the latter were much more altered than the former. This confusion of the Cambro-Silurian and Cambrian will be referred to again.

¹ In the Old World the terms Lower Silurian, Upper Silurian, Devonian, and Lower Old Red Sandstone, are very much connected together. Selwyn, however, in his writings, seems to have adopted for the older rocks Phillips' term, Cambro-Silurian; and for the newer, Devonio-Silurian: as these are very expressive they will be used in this Paper.

² In connexion with this phenomenon it may be mentioned that, in the Belvoir section (Cambro-Silurian), county Clare, there are fossiliferous and jasperized rocks alternating. The reason of the different degrees of action in the county Wexford rocks I have attempted to explain in the "Geological Survey Memoirs."

The Cambrians of S. E. Wexford show some peculiar phases in metamorphism. Go northward, along the coast from Carnsore, by Carne to Greenore, and you meet, first, oligoclastic porphyritic granite; then oligoclastic coarse gneissic granite, which merges through gneiss into schist, the gradations from the gneissic granite to the gneiss being apparently abrupt; the section, however, is not very well exposed. If, however, you go a short distance westward, you find on the Saltee Island fine orthoclastic gneissic granite, in which are a few subordinate hornblendytes (hornblende-schist); while on the main land at Forlorn Point (Kilmore Pier), there are on the south shore-line hornblendytes, which by alternation of beds graduate into a considerable thickness of fine orthoclastic granitic gneiss, the latter to the northward having a hard boundary, outside of which are hornblendytes and other schists. This sudden change in lithological characters will be hereafter referred to when speaking of the Canadian rocks.

In the Mourne Mountains district, county Down, there are two distinct granite intrusions (Post-Cambro-Silurian (?) and Post-Carboniferous) (?), the latter, however, possibly Carboniferous. The Cambro-Silurian rocks of the area are altered (sub-metamorphic) by metapepsis, probably an adjunct of the genesis of the older granite; but subsequently, along the boundary of this granite, a newer action was in force, which developed a foliated structure in the adjoining granite, and altered a band of the sub-metamorphic rocks. This, as first pointed out by W. A. Traill, must have taken place subsequent to the intrusion of the granite, as the veins from it into the sub-metamorphic rocks are altered in a similar ratio to what has taken place in them. The rocks now occur in the following order:—

Granite,	}	The original granite intrusion.
Gneissic granite,		
Hard boundary.		
Gneiss band,	}	The original sub-metamorphic rocks.
Schist,		

The newer granite (Post-Carboniferous?) has not to any great extent altered the rocks adjoining it; but at the same time more or less signs of Paroptesis are apparent.

In the counties Galway and Mayo different phases of metamorphism can be studied. At first everything may appear to be under general law, but when details are entered into, here, as elsewhere, there are peculiarities hard to be explained.

Go northward from the ground westward of Galway town to Oughterard, across the strike of the rocks, and you first meet porphyritic oligoclastic granite, which changes nearly imperceptibly into oligoclastic porphyritic gneissic granite; while the latter graduates through gneiss into schist, and still further north, in the county Mayo, into unaltered Cambro-Silurians. Although in general the gneissic granite graduates into gneiss, yet in some places there is a hard boundary between them.

Go westward along the strike of the rocks and the change is not so gradual, as in places there are sudden jumps from granitic to schistose rocks; while in the latter you find outliers, sometimes having a nucleus of porphyritic oligoclastic granite, but more often porphyritic gneissic granite, which are more or less suddenly replaced by schist.

If, however, we go southward, there is a complete change in the character of the metamorphism; as in places along Galway Bay, margining the porphyritic oligoclastic granite, there are gneissic granites, usually orthoclastic and fine-grained, but having in them coarse-grained and oligoclastic beds; also to the S. E., at Galway town, there is a completely different group of rocks; as suddenly, adjoining the granite, and in a few small patches on it, or entangled in it, are schists principally hornblendytes. This small area of schists, apparently in such close proximity to the mass of the oligoclastic porphyritic granite seems very peculiar; this might, however, be explained by referring to phenomena that can be studied farther westward, near Roundstone and Slyne Head. As, however, it would take some time to do so, and the subject is in part foreign to the present inquiry, it seems sufficient to notice it without going into further particulars.

In the county Galway the coarse oligoclastic gneissic granites are evidently, especially across the strike, a portion of the series of gradation from metamorphic granite to schist and unaltered rocks; but in the Castlebar district, county Mayo, as first pointed out by Symes, there are undoubted intrusive masses or courses of a similar rock. These Mayo rocks seem interesting, as in the Canadian

Laurentians there are intrusive masses of coarse gneissic granite Labradorians or Norians of the Canadian geologist.

From the published writings in connexion with the oligoclastic granite and associated metamorphic rocks of the county Donegal, it is evident that the sequences are very similar to those in the counties Galway and Wexford, there being a mass of granite that graduates in some directions through coarse oligoclastic gneiss into schists; while in other places, similar to those on the south of the Galway mass, it is margined by fine orthoclastic gneissic granites. At the same time, however, as a general rule, the boundary between the more intensely altered rocks and the sub-metamorphic rocks seems to be more marked than usual. This, however, from the peculiar faults and dislocations of the rocks, should be expected.

It is unnecessary now to dwell longer on the Irish localities, more especially as hereafter some of them will have to be mentioned in detail; but I would again call attention to certain traits in metamorphism. Years ago I pointed out that in the West Galway and Mayo district, the planes of foliation of rocks in the second stage of metamorphism¹ followed the planes of the more conspicuous structures in the original rocks, whether these be due to lamination, cleavage, oblique lamination, spheroidal structure, concretionary structure, or any of the peculiar structures found in calcareous rocks; while in the typical granitoid gneiss all the original structures, except the planes of stratification, are nearly always obliterated, the new foliation being vertical, or nearly so. As in many places there is a hard boundary to the granitoid gneiss, it may be suggested that it is possible that its coarse foliation is due to a newer and subsequent metapepsis, which extended only to certain limits, intensifying the foliation inside these, while it did not affect the rocks outside them. We may now proceed to the metamorphic rocks of Canada.

Why is metamorphism in Canada so much restricted to the older or Archæan rocks, when, in our little island, we have metamorphosed Cambrian, Cambro-Silurians, Devono-Silurians and Lias?

A striking feature of the Canadian Laurentians is the massive coarseness of the foliation in some of the gneiss. This, as just

¹ See "Geology of Ireland," chapter x.

mentioned, appears to me to be due, not to excessive metamorphism at one and the same time, but to the rocks having undergone two, three, or even more, successive, but independent invasions of metamorphism, which developed instead of obliterating the laminæ due to the earlier metamorphisms. Excessive metamorphic action in a portion of an area will change the rocks into granite ("Geology of Ireland," chap. x., p. 175), but if a milder metamorphism invades rocks at different successive times, the plates or laminæ should be more and more developed. This can be seen on a small scale in various places in Ireland, the best, perhaps, being the gneiss developed adjoining the already-mentioned "Slieve Croab granite," county Down, Mourne Mountain district ("Geol. of Ireland," chap. xi., p. 192). In general, in the Irish localities, the metamorphism seems to be due to metapepsis succeeding paroptesis, or in other places to paroptesis coming after metapepsis; while in some places one period of metapeptic action appears to have followed a former one; and we can well imagine that very old rocks may have been subjected at various times to metapepsis, with, in more limited areas, paroptesis. In the west of county Galway (Connemara), to the north-westward of the tract of metamorphic granite, there are the previously-mentioned outliers, in part granite and in part granitoid gneiss. These, I would suggest, may probably be patches which at first were altered by paroptesis, while subsequently, when metapepsis invaded the country, they became granitoid-gneiss, while the adjoining rocks were changed into rocks of the "schist series." Such a supposition would account for there not being the ordinary gradation from the granitoid gneiss through the "gneiss series" into the "schist series."

The coarse foliation can be well seen and studied in the gneissic granite called Labradorians by the Canadian geologists, and marked "La" on Selwyn's new map. This rock has no exact representative among the Irish rocks. The rocks nearest in structure are, perhaps, the gneissic granite ones of the barony of Moycullen, county Galway, which are evidently of metamorphic origin, and probably of Cambro-Silurian age; the gneissic-granite protrusions and courses in the Castlebar district, county Mayo, which evidently came up originally as intrusions through the associated Cambro-Silurian rocks; and the metamorphic gneissic granite of the Erris district, also in the county Mayo. There are also in the county

Donegal some rocks in the Glen Lough district nearly allied to those just mentioned, but not, however, as coarsely foliated. As these Canadian rocks occur as intrusions, the rocks of the Castlebar district are more allied to them than the others.¹

It may also be pointed out that some of the varieties of granite are remarkable for their massive crystallization, more especially the pegmatites. This, among others, is very conspicuous in the white mica pegmatic of the Vale of the Du Lievre, the felspar usually being in considerable masses, while the white mica can be got in plates over nine inches square. The granites of the pegmatic group are called Endogenous by Sterry Hunt, and he suggests that the minerals crystallize out of solution. Such a supposition can easily be understood when pegmatite is found in small masses or lenticular veins; but it is not so easily conceived when we have to treat of considerable tracts. At the same time it is perfectly possible that in a great thickness of rocks there may have been vast vugs filled with mineral solutions, out of which the minerals of the pegmatites crystallized. From what I have seen in Ireland, I would suggest that this massive crystallization may not be due to subsequent metamorphic action. In the Aughowle district, county Wicklow, there is a pegmatite locally called "Bastard granite," while a variety of it is the "Plumose granite" of Jukes: this is somewhat like the Canadian pegmatites, although not as coarsely crystalline: it is evidently newer than the normal granite of the Leinster type, and, consequently, ought to be younger than the time of the Regional metamorphism. If this is the case, the present structure is probably the original one, from which we may suggest that the Canadian rocks are also in their original form; but, at the same time, as they are so much older they may have been further developed by metamorphic action.

In the province of Ontario and the neighbouring portion of the province of Quebec, the Archæan rocks are divided into Huronians and Laurentians. Selwyn has pointed out that such divisions seem to be more lithological than geological; while, as far as I can learn, Logan has not stated that he had found any proofs of their being geological groups. On the other hand, however, Dawson (Sir J.

¹ Mixed up with the other were eruption rocks, but the latter were portions of the different groups.

William), Sterry Hunt, and others, seem to insist that they are not only lithological but also geological groups.

A rock that seems to be considered a typical Ontario Laurentian is a pinkish or flesh-coloured fine-grained gneiss, hand specimens of which are undistinguishable from some of the fine gneissic rocks of the Cambrians of south-east Wexford (Saltees and Forlorn); the Cambro-Silurians of the counties Wexford and Wicklow; the Cambro-Silurians, county Galway; the Cambrians (?) of Erris, county Mayo; and the Cambro-Silurians, or Cambrians (?) of county Donegal. Some of these metamorphic rocks—as for instance those of Forlorn Point—were evidently at first felspathic, and probably tuffose stratified rocks; this was probably the case also in many places where similar gneiss occurs in the counties Galway, Mayo, and Donegal; but there are also in those places and in the county Wicklow similar gneisses which evidently were originally intrusions of felstone or felsite. In the high ground called Chelsea Mountains, Vale of the Gatineau, Ottawa county, there is a granitoid gneiss very like some of those of Galway, Mayo, and Donegal; that is, a rock intermediate in structure between the typical gneiss of Ontario and the gneissic granite of Chicoutimi, Montcalm, &c., province of Quebec—three different rocks, all somewhat similar in constituents, but having been subjected to different degrees of metamorphic action.

In connexion with the Chelsea district may be mentioned the schistose rocks that occur in the lower ground nearer Chelsea. Associated with these are some peculiar calcareous rocks that are identical with some of the rocks of the “Ophiolyte and Dolomyte series” of the Twelve Pins or Connemara district, county Galway (“Geology of Ireland,” chap. i., p. 21). These rocks of Connemara have been suggested by King of Galway, to be of Cambrian age, and my examination of the country goes to confirm that opinion.¹

It is necessary before we proceed further to mention some peculiarities in connexion with certain Irish calcareous rocks. There are, associated with the Lower Carboniferous sandstone of Clare,

¹ These rocks, although undoubtedly some of the very oldest in the county Galway, have not been included in the so-called Archæan rocks; those called Laurentians being evidently of newer age, which has been proved by their fossils to be of Cambro-Silurian age, and have been so classified.

the Devonio-Silurians of Galway and Mayo, and the Cambro-Silurians and Cambrians of Donegal, Sligo, Mayo, Galway, Waterford, Wexford, and Wicklow, calcareous rocks which are more or less intimately connected with basic eruptive rocks, and which appear to me to be in some way the result of vulcanicity ("Geol. of Ireland," chap. xii., p. 194). In the township of Buckingham, and elsewhere in Ottawa county, there are apatites that make very like the above-mentioned Irish Cambro-Silurian and Cambrian limestones, they being associated and entangled with basic eruptive rocks—and, perhaps, it may be allowable to suggest, that in some way not as yet explained the carbonate is replaced by the phosphate of lime by methylosism—a somewhat allied case being the change of pyroxene into amphibole by some unknown paramorphosic action.

The rocks which *par excellence* are called Laurentians belong to the lithological groups for which I have suggested the names "Gneissic Granite" or "Granitoid Gneiss" and "Gneiss Series"; while the Huronian rocks *par excellence* belong to the groups called "Schist Series" and "Submetamorphic rocks."¹

To these general classifications, however, there are exceptions; because, as in the Ottawa country, there are found in the districts, at the present time mapped as Laurentian,² more or less extensive tracts of schistose rocks; while, on the other hand, in the Huronian tracts there are some gneiss. This is similar to what occurs in the Old Country, as rarely will you find rocks of the "Gneiss Series," or even of the "Gneissic Granite," in which subordinate schistose rocks do not occur; while in the "Schist Series" there are always in places gneissoid rocks, and even in places among the "submetamorphic rocks." As already mentioned, the Laurentians and Huronians are undoubtedly lithological groups; but are they also petrological, that is, geological groups? This we have now to consider.

In the province of Ontario there are numerous junctions of the

¹ These different groups are fully explained in chapter x., page 177, of the "Geology of Ireland."

² Selwyn specially mentions that the present boundaries and mapping are only provisional, and that hereafter many tracts of Huronian rocks will probably be found in the areas at present mapped as Laurentian.

Huronian and Laurentian rocks, those that have been most studied being in the neighbourhood of the Canadian Pacific Railway, between Port Arthur, on Lake Superior, and Winnipeg. Of these, that to which greatest attention has been directed is the junction at the rapids from the Lake of the Wood close to the settlement of the Rat Portage. This junction is very well exposed at the rapids, and in other places, and is stated by Sir W. J. Dawson and others to be a "Fault boundary." Such a statement cannot be lightly passed over, especially by an Irish geologist, when he remembers the boundary between the Cambrians and Cambro-Silurians in south-east Ireland. These boundaries are so intricate in different places in the county Wicklow, especially in the neighbourhood of the Carrick Mountain and Glenealy, and in the county Wexford, at Poulshone and Barrow, that it required a man of special powers of observation, such as Jukes, to be able to point out the unconformability of the two groups. As, from the light supplied by him, I have been able to satisfy myself that such intricate unconformabilities may occur, I would be rash in stating that very similar unconformabilities may not occur in Ontario; yet, at the same time, I may be allowed to make suggestions, or, in the present case, to state that I see no reasons for supposing that there is necessarily an unconformability between the Laurentians and Huronians. First, in no place that I could hear of, in Ontario or Quebec, are the Huronian rocks found resting on the upturned edges of the Laurentians, while all the junctions seem to be such as what we should naturally expect to find at the meeting of two distinct lithological groups. This question, however, has got into a tangle, as it must be allowed that in Europe, at the present time, our geological maps should more properly be called lithological, as the major portions of the divisions marked on them are lithological and not geological divisions. This is specially the case with the Cainozoic and Mesozoic, as the different groups in them are merely lithological groups; but it is not so much the case in the older (Palæozoic), as in it the "formations" seem in a great measure to be geological groups; but the sub-divisions are not so. Take, for instance, the sub-divisions of the English Devonian-Silurians and those of the Cambro-Silurians, and look for them in the same order in either Ireland or Scotland, and the result will be that they are found to be mixed up confusedly. The undue pro-

minence given to lithology in modern Geology seems to me to be a most important consideration in the present inquiry; as what has to be proved is not that the Canadian Laurentians and Huronians are different lithological groups, but that they are different stratigraphical groups. The former is a plain fact; but I know of no positive proof that has been brought forward in favour of the latter.

The mistakes that may occur by substituting lithology for stratigraphical and palæontological geology, can be illustrated by facts observed in Ireland. For the uppermost groups of the Irish Cambro-Silurians, I have suggested the name "Slate Series," as, in general, they consist of a great thickness of argillaceous rocks, and in them are found all the principal veins that have been worked for roofing-slate; while for the lowest group of the Cambro-Silurians I have proposed the name "Black Shale Series," it also consisting in a great measure of argillaceous rocks. In the north of the county Wexford, a few miles N.E. of Carnew, in the "Slate Series," a great thickness of grit comes in; while in the Erriff Valley, county Mayo, a great thickness of nearly similar grit makes its appearance in the rocks of the "Black Shale Series." Now if the rocks of these two distinct areas were subjected to an equal amount of metamorphic action, we should have two groups stratigraphically very distinct, but lithologically similar. As in both localities the change from arenaceous to argillaceous is quite sudden, there would be hard boundaries in both places between the metamorphosed grits and the metamorphosed slates.

In different places in Ireland there are tracts of gneissose rocks more or less similar to the Canadian Laurentians, yet evidently they belong to a newer geological group. Of these, those in the Carnsore district, S.E. Wexford, are probably metamorphosed Cambrians; while those of north Wexford, in the Croaghan Kinshelagh range, undoubtedly belong to the upper group ("Slate Series") of the Cambro-Silurians; those of the counties of Galway and Donegal in part belong to the Cambro-Silurian, and perhaps in part to the Cambrian.¹ In Erris, N.W. Mayo, they may be

¹ In both these counties these gneissose and granitic rocks are evidently in part younger than associated rocks which are either unquestionably or probably of Cambro-Silurian age.

metamorphosed Cambrians ; in east Mayo, Sligo, and Tyrone, they are, probably, Cambro-Silurians or Upper Cambrians ; that is, the representation of the Arenig rocks of Wales ; while in the county Antrim, in the Ballycastle district, they may be either Cambro-Silurian or Cambrian age. Lithologically, these are all similar, but in reality they are of very different ages.

It should be pointed out that, as a general rule, hard, well-defined boundaries are characteristic of excessively altered rocks ; while in unaltered rocks hard boundaries are the exception, one group usually graduating into another by alternations of the different kinds of rocks ; thus limestones in general graduate into shales, and the latter into grits ; while grits will first alternate with shales before the latter entirely predominate. The subject of hard boundaries to metamorphosed rocks I have already discussed in Chapter X. of the "Geology of Ireland," where it is shown that, in general, small metamorphosed tracts in large unaltered areas have hard, well-marked boundaries ; while here I would point out that, in large areas of granitoid rocks, such as those of Galway and Donegal, there are proofs that the action which changed the rocks into their present condition invaded them long after their accumulation ; as prior to their metamorphism they were upturned, contorted, displaced by faults, while the consequent ruptures and breaks are now more or less sealed up. The breaks in the less altered rocks are much more numerous than in the granitoid rocks, those that are conspicuous in the latter being common to both.

Many of the facts above mentioned respecting the Irish rocks may not bear directly on the Canadian Archæan rocks ; but they do so indirectly, as they show that too much reliance must not be placed on mere lithological characters. Furthermore, although in the Canadian Archæans there are many rocks of which there are no equivalents in Ireland, yet in the latter country there are also many that are. It has already been shown that there is a great similarity between the gneiss and the calcareous rocks of the two countries, and this is even greater if we study the metamorphosed basic-eruptive rocks. In the section between Port Arthur and Winnipeg there is scarcely any rock of this class an equivalent of which could not be found in some one or other

locality of the Irish metamorphosed Cambrians or Cambro-Silurians.¹

To return to the boundaries of the Ontario Laurentians and Huronians: it would appear to me that they are more lithological than stratigraphical, as in no place does there seem to be a regular unconformability or even an overlap of the Huronians on the Laurentians, while on both sides of the boundaries there are striking similarities in the directions and dips of the beds in each class of rocks, while all the cracks and faults in the supposed older rocks occur also in the supposed newer.

If it be allowable to compare small things with great, a parallel may be drawn between the section of the metamorphosed Cambrians of the Forlorn Promontory, county Wexford, and that at the rapids out of the Lake of the Woods, one being a pocket-edition of the other. At the Forlorn section, going southward, we first meet typical schists, which are succeeded by gneiss, there being a hard boundary between the two; the gneiss, however, to the southward begins to alternate with beds of schist, and before the Point is reached all the rocks are schists. In the Canadian section, going northward, you first cross schists, then you come to a hard boundary, north of which is gneiss; but still further northward in the gneiss there are subordinate schists, which seem in one place to be of considerable thickness, as the water has cut out a very considerable bay apparently into rocks of a more frail character than the gneiss.

I am aware that Sterry Hunt and others have suggested that these older rocks were accumulated under very different circumstances from the younger ones; they being in a great measure more chemical than sedimentary accumulations. Such a supposition, however, appears to me, now that I have seen the Canadian rocks, to be unnecessary, if not untenable, as these supposed chemical accumulations are in a great measure similar to much younger rocks in the Old Country, where their characters, as can be proved by ocular demonstration, are not due to chemical accumulation, but to metamorphic action long subsequent to their first accumulation.

¹ Years ago I examined the collection of Canadian Archæan rocks, sent over by Sir W. Logan to the Royal School of Mines, London, to illustrate his Report, and in them I only found a few rocks that did not occur in the Cambrians and Cambro-Silurians of West Galway.

Some of the suggestions that I have made in this Paper may have been already published by American Geologists, who have had better opportunities than I have had of studying the rocks. If so, I apologize to them; but at the same time I would assure them that I am at present unaware of their having made the suggestions.

NOTE ADDED IN THE PRESS.

I learn from Dr. George Dawson that, during last summer's work, some important changes, which are shortly to be published, have been made in the classification of the Labradorians or Norians.

XLV.—NOTES ON THE COAL SEAMS OF THE LEINSTER AND
TIPPERARY COAL-FIELDS. BY G. H. KINAHAN,
M. R. I. A., &c. (Plate XIV.)

[Read, January 19, 1885.]

THE earliest attempts to classify the coal-seams of the Leinster and Tipperary fields seem to have been those of Griffith, at the beginning of the century; the results of his explorations having been published about the year 1814. Many years afterwards Messrs. B. B. Edge, and A. Jacob proposed a different classification from that of Griffith for the coal-seams of the Leinster field; and the latter, after I had examined the field, was adopted by Jukes in the "Geological Survey Memoir," published in 1859.¹ After Mr. J. M'Carthy Meadows had proved the coal in the new pit at Modubeagh, he, in the *Geological Magazine* for March, 1874, advocated, for the most part, the classification of Griffith.

As I have lately been able to examine the facts proved, or to be learned, from the pits and other workings in the district, since I examined the field in the year 1858, perhaps I may be allowed to lay the results of my investigations before the Society.

In my "Geology of Ireland" it is pointed out that, in 1878, the section of the eastern portions of the Leinster coal-field was nearly quite clear; as also that of the central portion down to a certain depth; but that the relations between the coals of those portions of the field had not been proved; because in the central portion there were no coals nor measures, that could positively be stated to be the same as any of those in the eastern division. A general section of the measures that had been at that time, and have been since, proved in the central portion of the field has been compiled by Messrs. Popping and Edge, which proves a *Crow coal* about 93 yards (279 feet) below the *One-foot coal*.

In Meadows' Paper (March, 1874) he states that he considered my classification wrong; as, instead of the Modubeagh coal being the representative of the "Old Colliery Three-foot coal," he believed that it was from 220 yards (660 feet) to 280 yards (840 feet) below it. These thicknesses were from calculation, and therefore must

¹ About the year 1870 I modified the statements then published; which modifications subsequently appeared in my "Geology of Ireland," chapter vi.

be to some extent uncertain ; but the soundness of his views seems to be more or less proved from the subsequent researches by his assistant, Captain Sutcliffe. The latter investigator has carefully compared the measure passed through in the sinking of the new Modubeagh pit with those of the adjoining collieries ; and from these comparisons he came to the conclusion that the trial at Mayo was in the same measures as those at Modubeagh. If this suggestion proves correct¹ the great problem of the field is solved, and the measures ought to occur in an order similar to that given in Section 2, Plate XIV.

The reasons for Sutcliffe's supposition are as follow :—In the Modubeagh pit there is, at 50 yards (150 feet) from the surface, the *Crow coal* ; while 70 yards (210 feet) lower down, or 120 yards from the surface, is the *Foul coal* (called in the adjoining collieries *Ward's Seam*), the “Main coal” being 48 yards (144 feet) lower, or 168 yards from surface. In the Mayo trial a *Crow coal* was cut at about 18 yards (55 feet) from the surface, and at about 61 yards (183 feet) deeper a second. The latter coal is not exactly similar to the *Foul coal* or *Ward's Seam*, or at the same depth below the *Crow coal* ; but the associated measures above² and below it, as far as proved, are very similar to those in the Rushes and Modubeagh pits ; on which account Captain Sutcliffe considers the coals to be the same. As already mentioned, there is, according to Popping and Edge's section, a *Crow coal*, about 93 yards (279 feet) below the *One-foot coal*, with which occurs the *Jarrow Channel*, a *Crow coal*, the measures above and below which are more or less similar to those associated with the *Upper coal* in the Mayo trial, and those in connexion with the Modubeagh *Crow coal*, which has led Captain Sutcliffe to consider that in these sections there is found the representatives of one and the same coal (Modubeagh *Crow coal*). The comparison between these different sections appears to afford good presumptive evidence that the calculations of Messrs. Meadows and Sutcliffe are correct ; the main or profitable coal (*Rushes coal*) of the measures in the eastern division of the field lying about 209

¹ Mr. B. B. Edge points out “if the small coal in the Mayo pit is the representation of the Modubeagh *Crow coal*, there can be only 180 feet between it and *Ward's Seam*, and not 210 feet, as in Modubeagh.”

² In the Modubeagh pit there was a bed of fire-clay 21 feet over the *Crow coal*, while in the Mayo trial there is one 13 feet above the thin coal.

yards (627 feet) to 216 yards below the *One-foot coal* (*Jarrow Channel*) of the central division. At the same time this has not been positively proved; but a continuation of the Mayo trial to a further depth of about 25 to 35 yards (75 to 105 feet) ought to settle the question.

Near Castlecomer Cottage, in the lane leading to the sandstone quarry, there is a hard, grey, calcareous shale containing Lower Carboniferous fossils. If Sutcliffe's classification is correct, this should be found in the measures in the Modubeagh pits and the Mayo trial. But after minute inquiry I cannot find that any beds like it have been observed at either of those places.

GENERAL SECTION (CAPTAINS SUTCLIFFE AND MEADOWS).

Peacock or Surface coal, with 12 feet drift over it:

Strata, about 45 feet = 15 yards.

Stony coal:

Strata, „ 21 „ = 7 „

Double seam:

Strata, „ 111 „ = 37 „

Old Colliery Three-foot coal:

Strata with "Crow Coal" about
45 feet below Three-foot, . . } „ 180 „ = 60 „

One-foot coal with Jarrow Channel:

Strata, „ 279 „ = 93 „

Crow coal, Modubeagh:

Strata, „ 204 „ = 68 „

Ward's seam, or Foul coal:

Strata, „ 144 „ = 48 „

Rushes, or Modubeagh coal:

Strata, 180 feet to 210 „ = 60 to 70

Kingscote, or Bullring coal:

Strata, „ 300 „ = 100 „

Gale Hill coal:

Middle measures, „ 800 „

Lower measures, „ 500 „

Carboniferous limestone,

The second, or *Lower Towlerton coal*, mentioned in my "Geology of Ireland," does not appear to be satisfactorily understood. To the

northward, in the Rushes Colliery, there does not appear to be any representation of it; but immediately north of Towlerton, in the townland of Woodlands, or Newtown Harpole, two coals are recorded; while it was also found in some of the pits in Towlerton; but in other pits, sunk to search for it, it was not found. Possibly here, as at Coorlaghan, there may be in places a "splice," being portions of the one bed with a "horse" between them, or, as suggested by B. B. Edge, there may be an overlap, as found in the Doonane Colliery. In the Newtown Harpole bore-hole, and in one pit in Towlerton, there was about 50 feet of strata between the two coals; elsewhere, however, in Towlerton, it is said to have risen up towards the *Old Towlerton coal*.

Since the year 1859 the continuous workings on the *Jarrow Channel* have proved it to be a rather remarkable accumulation. In 1859 it was generally supposed to have some sort of a connexion with the *One-foot coal*, but the relations between the two were quite obscure; some ten or more years afterwards, when a pit had been sunk and workings commenced on the portion of the channel under the Clogh royalty, the proprietors ran a drive northward, for 680 yards, which proved that the Jarrow coal lay in a washout or channel; the coal at the margin of the channel joining into the *One-foot coal*. The accompanying section, Pl. XIV., fig. 1, for which I am indebted to Mr. Meadows, is a tracing from the working plan. From this we learn that for 264 yards the floor of the coal rose; while on the brow of the rise it joined into the *One-foot coal*, "a regular coal" on a "fire-clay and seat;" while under the coal of the channel "there is no fire-clay or seat, there being only a sort of shaly seam between it and the country rocks." (*See note at end.*)

The washout, in which the *Jarrow Channel* occurs, is both important and peculiar.

If the great N.E. and S.W. Coolbaun fault be taken as a base, to the northward of it, this washout forms a more or less regular horse-shoe, extending from the Geneva Colliery, on the east, northward along the valley of the Dinan to Clogh, and thence westward to Massford, and southward to Coolbaun. South of the N.E. and S.W. Coolbaun fault the exact position of the channel has not been proved, as the only workings are to the eastward, at Monteen and Kilgorey, and to the westward, at the Rock Colliery (Augharenagh), places lying nearly east and west of each other.

In connexion with the Rock Colliery, Mr. Joseph Dobbs points out that no batrachian or other fossils, such as have been found in the northern channel, have been there met with; and he suggests that possibly there might have been two channels in connexion with this *One-foot coal*—that to the north or the *Jarrow Channel* being separated some way or other from the *South* or *Rock* and *Kilgorey Channel*. The measures found in connexion with the coal of the *Jarrow Channel*, when compared with those found in connexion with the coal of the *Rock* and *Kilgorey Channel*, may add weight to Mr. Dobbs' suggestion.

To the northward of the Coolbaun fault there is a remarkable circumstance connected with the washout, which is, that the present valley of the Dinan river nearly coincides with it. Whether this is a mere accidental coincidence or is due to some natural cause it is hard to determine.

The accompanying section (Pl. XIV. fig. 1), with the small section (fig. 2), represent the character of the channel as proved in the Clogh and Jarrow Collieries; while the old working at Geneva, to the S. E., and the new ones at Massford, to the westward, suggest that in those places also the channel is of a very similar character and width.

From this section it would appear as if the full channel was, on an average, about 350 yards (1050 feet) wide, while the profitable coals in its deepest portion were not more than 200 yards (600 feet) wide; the greatest depth of coal being four feet, which more or less gradually lessened towards the margins, especially the north margin.

Another peculiarity of the *Jarrow Channel*, which does not appear in Meadows' section on account of its small scale, is that, as we proceed towards the edges, especially southward, eastward, and westward, there are breaks or sudden lessening of the thickness of the profitable coal, locally called "troubles," or "faults." This phenomenon is roughly represented in the sketch (fig. 2). The roof is continuous; but the floor of the coal rises, and on each rise or "trouble" (at *a, a, a*) there is only a sort of clayey culm, or *buddagh*, i. e., a mixture of coaly and clayey or shaly matter; while at both sides of the "trouble" the coal is found: on the channel side it is usually of the regular thickness, while at the other, or towards the edge of the channel, the coal gradually

thickens, to thin again when the floor rises. These phenomena, in connexion with the formation of the channel, appear important, as will be mentioned hereafter.

It appears necessary to point out here, that in my previous writings and in those of later observers, a very important consideration has been omitted, or rather mis-stated, as the promiscuous calling of the seam *One-foot coal* and *Jarrow coal* leads to an erroneous impression; because although they are connected, the latter being an adjunct of the former, the *One-foot coal* is perfectly distinct from the *Jarrow Channel*; for although both may have been accumulating at one and the same time, their modes of formation were very different; one being almost entirely a drift accumulation, and the other a growth *in situ*. I have not met with any description of a coal similar to that in the *Jarrow Channel*, but the probable explanation of its peculiarities would appear to be suggested by what can be observed as going on at the present day in various places in the Irish bogs. Numerous cases could be mentioned, both in the Irish lowland or Red Bogs, and in the mountainous districts. I will, however, draw attention to but one locality, which is specially illustrative—that is to say, the level bog-land in the neighbourhood of Muckanaghederdanhalla, Connemara, West Galway. In this locality there is a great expanse of low bog-land intersected by more or less regular wash-outs; some of the latter being fiords, while the majority of them are now marshes or sloughs; the latter having been, or being now filled in, by materials carried by wind, rain, and runlets from the adjoining flats, aided by the growth and decay of vegetation; while on the adjoining flats peat is accumulating in the ordinary way—that is, by the growth and decay of vegetation *in situ*. Some such more or less similar operations must have been going on in Carboniferous times, to account for the formation of the *Jarrow Channel*. The *One-foot coal* seems to be of a somewhat similar origin to the flat bog, being due to the growth and decay of vegetation *in situ*, while through it there ran a washout, now the *Jarrow Channel*; it having been subsequently filled in by argillaceous and vegetable matter carried into it by wind, rain, and runlets, the accumulation being aided by the growth and decay of aquatic plants. Besides the plants in the nearly stagnant or sluggish waters, there lived fish and batrachians; and these, in course of time, as the filling-in

process proceeded, were pounded into small spaces, when eventually they died, and were buried.¹ The character of the channel and its accumulations would appear to suggest such conclusions; as the form is so similar to those in our flow-bogs or sloughs, while the steps (*troubles*) in the floor of the coal are similar to those under such peaty accumulations. Moreover, all of the channel accumulations are, for the most part, sedimentary, except perhaps the *Bottle coal*. This coal is peculiar; its name having arisen from the great similarity, both as to appearance and fracture, between it and bottle glass. Its origin is puzzling; as although in some places it appears in mass, in others it is mixed up irregularly with the members of the regular stratified accumulations; and nowhere, as far as I could see, has it a lining structure to suggest that it was either a sedimentary deposit or due to the annual growth and decay of vegetation.²

At the time Mr. Meadows published his classification of the Leinster coals, he endeavoured to frame a scheme of correlation between them and those of the Tipperary or East Munster coal-field; but a comparison between the Sections 1 and 2, Plate XIV., demonstrates how fruitless any such attempt must be.

On examining the different published records of the Tipperary field, it will be seen that *all coals, no matter how valueless*, are given a place and a name—thus giving them an undeserved value. While, on the other hand, in all the records of the Leinster field, more or less of the minor coals are left out, although they are just as important and continuous as the minor coals in the Tipperary field. This, therefore, is a unique feature in Section 2, Pl. XIV., as in it all the minor or *Crow coals* that are continuous, being recorded in the different sections of pits and bore-holes, are given in their proper places. This appears expedient, as they are very valuable indications to the colliers as to the depth at which they will probably find the different coals which they overlie.

I would here again specially mention, as has already been done

¹ The above seems to be now the general idea in reference to the Jarrow Channel; as I have heard very similar notions expressed by Messrs. Edge, Meadows, and Dobbs.

² It has somewhat the appearance of a chemically formed, or partly chemically formed, rock. This, however, may have been induced by the metamorphic action that has more or less changed the rocks of these and the majority of the Irish Coal Measures.

in my "Geology of Ireland," that in regard to the Co. Tipperary, "In this field every stratum, from the highest in the limestone to the highest of the coal-measures, can be seen and measured." All the strata between the *Upper Glengoole coal* and the *Main coal* were hammered and measured by the late Mr. O'Kelly, Mr. Wynne, and myself, in the Glengoole level, while subsequently they were re-measured by O'Kelly. Moreover, there is on the surface a very continuous section, which was carefully examined and measured by O'Kelly and myself, and subsequently by the late Mr. Jukes, accompanied by O'Kelly. I am informed by Mr. Meadows that he not only examined and measured this section, but also others in the field, and found O'Kelly's measurements substantially correct: if anything out, they are a little short of the actual thickness. It may be mentioned that from the measurements given by the Glengoole level, Mr. O'Kelly and myself were able to localize the outcrop of the coal that was afterwards wrought between the Collieries and Killenaule.

Of the eight coals that appear in Section No. 1, three at least—the *Stinking coal*, *Maher's Vein*, and *Hanley's Vein*—are commercially valueless; while the total thickness of the measures in which the coals occur is about 1200 feet.

In the Leinster coal-field there are at least eleven coals and perhaps twelve (*Lower Towlerton*). Of these, the *Gale Hill*, *Modubeagh*, *Crow*, and *Jarrow Crow* coals, are commercially valueless; while the *Kingscote* or *Bullring*, the *Ward* or *Foul*, and the *One-foot* coals (irrespective of the *Jarrow Channel*) are not of much account; the more profitable coals being the *Modubeagh* or *Rushes*, the *Jarrow Channel*, portion of the *Foot coal*, and the old *Three-foot coal*; these occurring in a thickness of strata of about 1500 feet. There were also the upper coals in Coolbaun Hill that are now worked out.

The Sections Nos. 1 and 2 indicate that in the lower portion of the Leinster section there are more coals than in the corresponding thickness of the Tipperary section; also that opposite the portion of the latter, in which the valuable coals occur, there are no coals of any value in the Leinster section, except the *Jarrow Channel*, which is not a regular coal, being only an accidental adjunct to the *One-foot coal*.

It may be said that as the lower and middle measures of the Tipperary field are about 1500 feet thick, while those of the

Leinster field are only about 1300 feet, the difference should be taken off the base of the coal-bearing portion of the latter; but even if this were done (which, I believe, would be absurd, as the measures below the *Gale Hill* and *Stinking coals* are very similar) it would not mend matters; not even if 300 feet were taken from it, and the *Kingscote coal* was supposed to represent the *Stinking vein*. In the latter case the *Main coal* would be about opposite the *One-foot* with its *Jarrow Channel*; but none of the other workable coals would come in at about similar heights.

From the facts that have been proved from the examination of all the Irish coal-fields, it appears a waste of labour and an unprofitable task to attempt a correlation of the Irish coals; as it has been proved that, although the Irish Coal-measures, as a mass or group, were accumulating at one and the same time, the individual accumulations were of different characters, even at places not far apart, this being specially the case in reference to those due to vegetable decay or the mineralizing of vegetable matter; none of the latter being on similar horizons, or even on nearly similar horizons, except perhaps the lowest coal of the different fields. Thus in the eastern portion of the Leinster field there appears to be in an equal thickness of strata more coals than in the western portion; while in similar thicknesses of the Leinster and Tipperary fields there are more in the latter; and in the Cork field more than in either. But if we go north from Cork into Limerick, Kerry, and Clare, the number, thickness, and quality of the coals rapidly changes; they being at the lowest in every way in the county Clare, and perhaps county Kerry. It is unnecessary to mention the coals of Ulster and Connaught, which differ so completely, as to their circumstances, from those which form the subject of this Paper.

NOTE ADDED IN THE PRESS.

It has been pointed out by Captain Sutcliffe, and can also be seen in the section, Plate XIV., fig. 2, that the thickness of the strata between the *Three-foot coal* and the *Jarrow coal* increases from the edge of the *Channel* to its centre, from 209 yards to 216 yards; while the underlying black shale has increased from a foot in thickness, at the edge of the *Channel*, to twelve feet or more at the centre or deepest portion.

A copy of Popping and Edge's section is deposited in the Mining Record Office, London.

XLVI.—ON TRILOBITES AND OTHER FOSSILS, FROM LOWER OR CAMBRO-SILURIAN STRATA, IN THE COUNTY OF CLARE. BY WILLIAM HELLIER BAILY, F.G.S., &c.

[Read, January 19, 1885.]

THE fossils I bring before your notice were described in the explanations to Sheet 133 of the Map of the "Geological Survey of Ireland," illustrating a portion of the county of Clare.

They were first discovered by Mr. G. H. Kinahan and myself, in a small exposure of light-brown shales, in the townland of Ballyvorgal south, on the western extremity of the Slievebernagh Mountains, near Six-mile-bridge.

These fossils consist principally of trilobites, of the following genera and species:—*Dindymene Haidingeri* (Barrande), *Æglina rediviva*, *Staurocephalus globiceps* (Portlock) (probably identical with *S. Murchisoni*); *Remopleurides*, sp. perhaps *Colbi* (Portlock): *Trinucleus concentricus*, and *Agnostus trinodus*, with the brachiopods *Orthis calligramma*, var. *virgata*, and *O. elegantula*; and a pteropod *Theca triangularis*, all characteristic of Lower or Cambro-Silurian strata of Caradoc Bala age. The first-named of these trilobites, identified by me with *Dindymene Haidingeri*, is new to Britain, occurring, I believe, in Bohemia. It is figured and described by Barrande in his fine volume on Trilobites, in his "Système Silurien du centre de la Bohème," 1st part Palæontologie, vol. 1, as characteristic of his fauna seconde, equivalent to Caradoc Bala strata.

At Belvoir, about half a mile south of Crag-bridge, there is another interesting section, described by Mr. Kinahan, also on the western flank of the Slievebernagh Mountains, where a section of black slates is exposed, Graptolites being the prevailing fossils. Their impressions, double forms of *Diplograptus pristis*, together with the coiled genus *Rastrites peregrinus*, are most beautifully impressed upon the shales.

XLVII.—ON THE PHYSICAL CHARACTERS OF CALCAREOUS
AND SILICEOUS SPONGE-SPICULES AND OTHER
STRUCTURES. BY PROFESSOR W. J. SOLLAS, M.A.,
D.Sc., F.R.S.E. (Plate XV.)

[Read, January 19, 1885.]

SILICEOUS SKELETONS.—Although in the great majority of existing sponges the skeleton is of a siliceous nature, it was supposed, until quite recently, by palæontologists, that in nearly all fossil sponges it was originally, as it usually is now, calcareous in composition; but since in structure it seemed to offer in no case any point of resemblance to that of existing calcisponges, it became necessary to refer the fossil sponges to an extinct order, related to the existing calcareous sponges simply by the chemical composition of the skeleton, and not in any way by its structure. In 1877, however, Professor Zittel and myself showed that the majority of fossil sponges are characterized by skeletal structures which resemble in the closest manner those of existing siliceous sponges, and we accordingly inferred that, originally siliceous in composition, they had since become calcareous. Such a substitution as this involved appeared to most geologists improbable, and some chemists went so far as to assert that it was impossible. It has now, however, become one of the accepted facts of science.

The difficulty which was felt in admitting such a substitution was no doubt due to an ambiguity of terms. "Siliceous" and consisting of silica were regarded as synonymous expressions, and we cannot wonder that a chemist would refuse to believe in the possibility of calcite replacing quartz. But in my Paper on Pharetspongia I pointed out that the siliceous material of sponge-skeletons differs very widely from quartz in its physical characters. "The latter is to all intents perfectly insoluble in carbonated waters, and most other solvents; it is crystalline, with a comparatively high refraction-index, and is composed solely of oxygen and silicon. The former, on the other hand, is colloidal, with a comparatively low refraction-index, is soluble in caustic potash and carbonated

waters, and consists of silica (probably one of the silicic acids) in intimate combination with organic matter.”¹

More recently M. Thoulet,² to whom apparently my results were unknown, has made some experiments which completely confirm the preceding statements, except with regard to the presence of organic matter in the sponge-silica. M. Thoulet found that by calcination certain sponge spicules which he examined lost 13·18 per cent. in weight; their specific gravity was determined to be 2·0 361 at 16·5° C.; and hence M. Thoulet concludes they are to be regarded as opal, which is only another name for consolidated colloid silica. My attention having been re-directed to this subject by M. Thoulet's observations I wished to determine exactly the refractive index of sponge-silica, but was met at once with a difficulty due to the form of the spicules, their shafts being more or less cylindrical, so that their surface is always strongly curved, never plane. It then occurred to me to take advantage of the fact that a solid body becomes invisible, or nearly so, when immersed in a liquid having the same refractive index as itself. The problem then was to find a fluid in which the sponge spicules could no longer be seen. Knowing the refractive index of this liquid, the refractive index of the spicules would also be known. Experimenting with various kinds of sponge spicules, including fragments of Lithistid skeletons, I found that the nearest approximation to invisibility, as seen under the microscope, was obtained when they were viewed mounted in chloroform, which possesses a refractive index of 1·449. This is very nearly the same as that of iridescent opal (1·446). Some colloidal silica, which I prepared some five years ago, and which has been hardening ever since, gave a refractive index of 1·47, being least visible when mounted in glycerine.

The refractive index of sponge-silica is therefore that of opal or colloidal silica, and not of quartz, and thus my earlier statements, and those later of M. Thoulet are confirmed. All difficulty, therefore, with respect to the substitution of calcite for silica in

¹ Sollas “On Pharetrospongia Strahani;” *Quart. Journ. Geol. Soc.*, vol. xxxiii. p. 254, 1877.

² Thoulet.—“Sur les spicules siliceux des éponges vivant.” *Compt. Rendu.* xcvi. pp. 1000-1.

sponge-skeletons is removed. Since diatoms and the siliceous teeth of molluscs have the same refractive index as sponge-spicules, we may consider it probable that the silica of organisms generally exists as opal.

The method of determining refractive indexes just described admits of a wide application, and with isotropic substances presents no difficulties; it may often be employed in many cases where other methods are impracticable. Thus I find that the glass of the Krakatoa ashes has a refractive index of about 1.51, and it would be possible to obtain a closer approximation than this were one furnished with a refractometer to determine the refractive index of the liquid employed: as it is I am obliged, when using a mixture of two liquids in order to obtain a mean, to find its refractive index by discovering what mineral of known refractive index disappears when immersed in it. The test mineral thus serves as a refractometer. I intend, however, for laboratory purposes, to provide myself with a series of fluids; each with an accurately determined refractive index, and ranging from 1.3 to 2.0, with a difference of 0.002 between each. One would then make coarse adjustments up to the second place of decimals, and conclude by obtaining results up to the third place. Of course accurate results can only be obtained by the use of monochromatic light, which should be similar to that of the mineral under examination.

The method provides an easy means of discriminating between similar species of minerals. Thus, leucite and analcime often closely resemble each other; and without finding the exact vanishing fluid, it is sufficient for their distinction to place them either in oil of santal, when the leucite becomes almost invisible, while the analcime stands out in sharp relief; or in linseed-oil, when the analcime is least visible, and the leucite most so.

With anisotropic substance the case is different; but the additional difficulties which these present may be met by the use of polarised light, at least when the mineral possesses planes of cleavage. Thus, to take the case of aragonite and calcite. We view them under the microscope between crossed nicols, a plate of quartz being interposed to restore the light. The fragments of both minerals are, to a great extent, bounded by cleavage planes. In aragonite the indexes are—minimum, 1.530; mean, 1.682; maximum, 1.686: in calcite, $\nu^e = 1.486$, $\nu^w = 1.659$; the value of

r^e will never, however, be this minimum; but for light passing perpendicularly through a cleavage fragment lying with one face on the microscope slide is about 1.56. If now both minerals be viewed mounted in Canada balsam ($r. i = 1.525$), or oil of cloves ($r. i = 1.535$), most of the calcite will never cease to show relief as it is rotated between the nicols; the aragonite, however, undergoes a marked change; parallel to the principal section of one nicol it stands out in bold relief, like a projecting rock; as it is rotated, it begins to flatten down, the brilliancy about its edges and angles fades, and, finally, when it has been rotated 90° , it has lost all relief, and appears as the merest film flattened out in the plane of the glass slide. The experiment is a striking one, and the discrimination between the two minerals may in this way be made in a very short time—a few minutes will suffice.

Another application will be found later on, where the refractive index of a calcite spicule lying in a definite position, having been determined for the extraordinary rays, the position of the optic axis can be deduced.

Specific Gravity.—By a method described later on, the specific gravity of the acerate spicules of a Renierid sponge, of a fragment of a Lithistid sponge skeleton, and of various diatoms, was found to be 2.04, a result in close agreement with that found by M. Thoulet for Hexactinellid sponge spicules. The reference-minerals (a term which will be understood after reading the description of the method) employed in this case were crystals of sulphur deposited from solution in carbon disulphide, and fused sulphur: the specific gravity of the latter is 1.98; of the former, 2.05.

Calcareous Skeletons.—Amongst the fossil sponges are some which, in 1877, offered great difficulties to the palæontologist. Professor Zittel regarded them as calcisponges, while I was inclined to group them with the siliceous sponges, at the same time expressing great uncertainty on the point.¹ Since then, the discoveries of Hinde and Dunikowski have thrown more light on these previously-obscure “Pharetrones,” and I have now not the least doubt that they must be relegated to the Calcispongiæ.

¹ Sollas, “On the Genus Catagma,” *Annals and Mag. Nat. Hist.*, ser. 5., vol. ii., p. 363.

Pharetrospongia, however, is not one of the Pharetrones, and is as certainly a siliceous sponge as they are calcareous.

Some observers have gone so far as to deny the possibility of a calcisponge being preserved in the fossil state, alleging that calcareous spicules, when kept in distilled water, decompose in the course of a year; as, however, I have calcareous spicules in my possession, which are as perfect now as they were originally, when placed in distilled water ten years ago, the force of this argument is weakened.

It becomes interesting to inquire, however, into the mineral state of calcareous spicules, *i. e.* whether they are composed of calcite, or aragonite, or of some combination of calcareous and organic matter. If we find that they consist of calcite, we shall have no difficulty in concluding that they may well be preserved in a fossil state, but the contrary, if they consist of aragonite; or, at all events, in the latter case their preservation will be rare and exceptional, and their structure will wholly disappear. As everyone, without inquiring into the matter, seems to have regarded them as calcite, I was quite prepared to find the contrary; the result, however, of my observations will appear in the sequel.

Refractive Index.—Most of the acerate spicules of *Grantia ciliatia* and *Grantia compressa*, the species with which I chiefly worked, disappear when observed between crossed nicols, in linseed oil, along one line of extinction (light being restored by a quartz-plate): along the other line of extinction, at right angles to the former, all the spicules disappear when viewed in carbon disulphide containing a little sulphur; their refractive indexes are then $\epsilon = 1.485$ and $\omega = 1.650$, most nearly agreeing with those of calcite.

The invisibility of the acerate spicules when mounted in linseed oil, and at the proper angle of extinction, is often absolute; they cannot be seen even with strong illumination under a Zeiss C.

Specific Gravity.—The difficulty of determining the specific gravity of calcareous sponge spicules by the methods of weighing, I found insuperable. They are so small, and so difficult to free completely from air, even with an air-pump, that I had to adopt some other method. Sonstadt's solution appeared to offer the best chance of success; but here again the small size of the spicules was a difficulty. This, however, was overcome by adapting the Sonstadt method to use with the microscope. An ordinary col-

lecting tube, fig. 1, T, about 2 inches long, and $\frac{3}{8}$ -inch in diameter, was cemented with plenty of Canada balsam to a glass slide, as in the illustration.

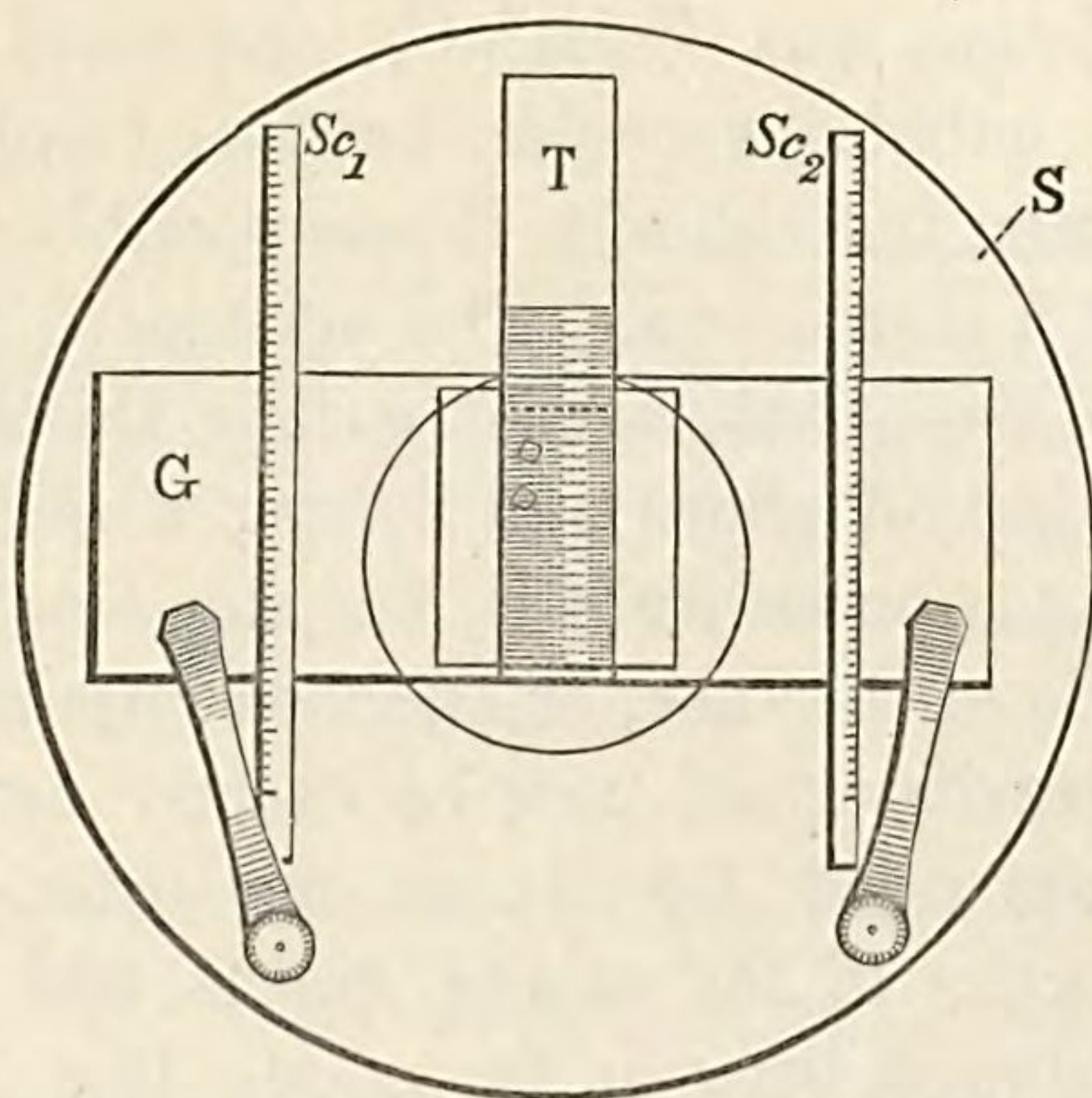


FIG. 1.

Arrangement for determining the density of minute objects under the microscope. S, stage of the microscope; Sc_1 and Sc_2 , the two scales; G, glass slide carrying the observation tube, T.

The object of using excess of balsam was to destroy optically the curvature of the side of the bottle. As the refractive indexes of Sonstadt's solution and balsam are not very different, this plan succeeded admirably. A thin cover-glass was similarly cemented to the opposite side (front face) of the bottle, which was thus optically flattened, front and back. Some Sonstadt's solution (sp. gr. 2.77) being introduced, a fragment of aragonite (sp. gr. 2.9) was dropped in; it at once, of course, sank to the bottom. Next, a piece of calcite (sp. gr. 2.7) was added; it floated on the surface. The spicules, lying in water, were freed as far as possible from air by boiling, and with the air-pump. With a dipping-tube the water and spicules together were taken up and added to the top of the Sonstadt's solution, where they floated. The tube was then left to stand in order that diffusion might take place. After some hours the water and Sonstadt's solution had become gradually mixed, giving a column of fluid with a specific gravity of about 2.4 at the top, and 2.77 at the bottom. The calcite and the spicules floated at different levels (the spicules being above), in layers of fluid having respectively the same specific gravity as themselves. A fragment of pure quartz (sp. gr. 2.65), and another of adularia

felspar (sp. gr. 2.58) were next added; the quartz sank to a level below the spicules, the felspar remained above. As the contents of the tube could be easily examined under the microscope with a 1-inch or even a $\frac{1}{4}$ -inch lens (Zeiss's C), one could make certain of the absence of air bubbles, vacuoles, or other troubles; and as the spicules could be seen individually, it was possible to determine the specific gravity of a single one. The spicules did not all lie at exactly the same level, but formed a zone thickest towards the middle, and thinning off above and below; a few stragglers were seen at some distance on either side, but this was owing either to adhesion to the side of the tube, or attached impurities.

The specific gravity could now be exactly determined. Two rectangular axes are ruled, fig. 2; on one distances are taken to represent the densities of the calcite, quartz, and felspar; on the other the exact distances between the middle line of each fragment as it floats in the tube are measured off.

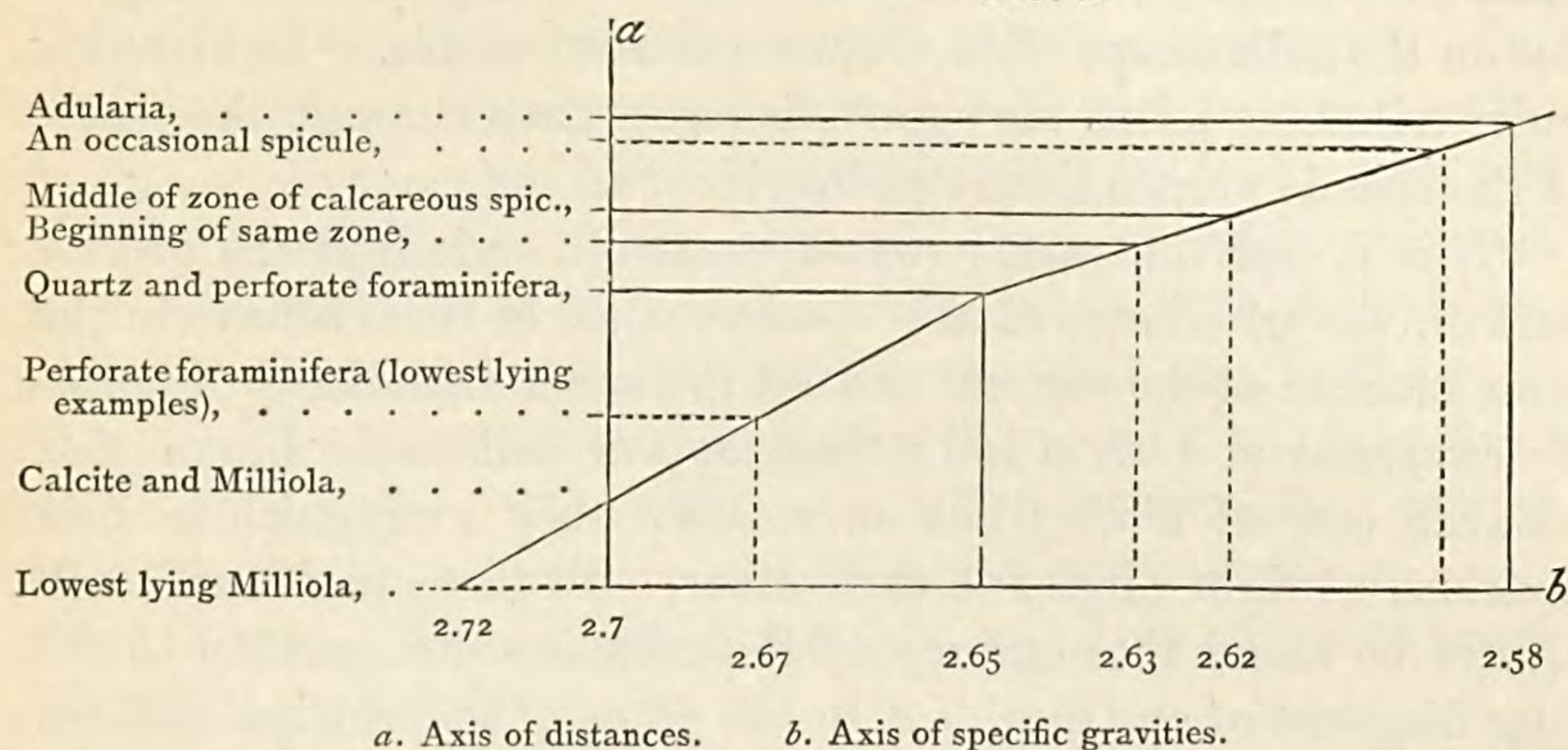
These distances were obtained by gumming two scales divided into millimeters on the stage of the microscope, at right angles to the glass slide carrying the experimental tube, *i. e.* parallel to this tube (fig. 1, Sc_1 and Sc_2). The calcite was brought into focus, and the position of one edge of the glass slide read off on the scales; the slide was then moved down till the quartz came into view, and the position of the slide again read off on the scales. The object of having two scales is obviously to ensure parallelism in the movements of the glass slide.

The specific gravities and distances being indicated on the rectangular axes, one constructs a curve which gives the change in density from one mineral to another in the tube.

The height of the zone of spicules being now indicated on the axis of distances, a line is drawn parallel to the other axis through it; from the point where it cuts the curve a perpendicular is let fall on the axis of specific gravities, and the point where it meets the axis gives the specific gravity. In this way the specific gravity of the spicules was determined to be from 2.61 to 2.63. They are plainly, therefore, not aragonite, and, arguing from the specific gravity alone, probably consist of calcite. The slight difference between it and them in specific gravity is no doubt due to the presence of organic matter; for within, a minute canal, filled with some kind of organic material, possibly spongin, occurs in the axis of the

spicules; and without they are surrounded by a thin sheath of a probably similar material. I find by calculation that, allowing for the organic matter a specific gravity of 1.5, it would require to be

FIG. 2.



present to the extent of $6\frac{2}{3}$ per cent. to reduce the total specific gravity of the spicules from 2.7 (supposing them to consist chiefly of calcite) to 2.62, the density found.

Optic Axis and Angles of Extinction.—Lying on the borders of the organic and the mineral worlds, the spicules of calcisponges offer many interesting problems for consideration. Their outer form, moulded by the organism, offers no crystalline outlines; their molecular structure, as will appear from the next series of investigations, is purely crystalline, not differing from that of calcite.

Hæckel, in his work on the calcisponges, regards the regular triradiate spicules as having a crystalline form, derived from a regular 12-sided pyramid; but as one cannot derive the angles of the sagittal and irregular triradiates by any known laws of crystallography from the more regular forms, one fails to see the grounds for such a view. The existence of precisely similar regular and sagittal triradiates amongst the siliceous sponges in which the mineralizing matter is purely colloidal also makes against this opinion. Were the regular triradiates of Hæckel placed within a scalenohedron in the position his view requires, the optic axis would pass through the centre of the spicule at right angles to its plane, and consequently, on viewing it through crossed nicols, it would remain obscure during a complete rotation about its axis in the

plane of its surface. This never happens with any of the triradiates of *Grantia ciliata* and *Grantia compressa*; but in a *Leuconia*, *L. botryoides*, which I have examined, many of the triradiates do fulfil this condition, remaining constantly extinguished as they lie flat on the microscope slide, between crossed nicols. In these regular triradiate forms the optic axis passes then through the centre of the spicule perpendicular to its plane.

This is not the case, however, with all, or indeed the greater part of, the triradiates of this species; most of them behave in the same manner as the sagittal and all the other triradiates of *Grantia compressa* and *G. ciliata*; these appear brilliantly illuminated between crossed nicols; but on rotation they extinguish in four positions at right angles to each other. In these positions it will always be found that one ray of the triradiate lies parallel to the long diagonal of one nicol, *i.e.* in the plane of its principal section. With the sagittal spicules it is the unpaired ray that has this position; with the regular and sub-regular triradiates, it may be any one of the three rays. In the same way the quadriradiates extinguish; and in their case it is always the apical ray which lies in the principal plane of the nicol at the time of extinction. The optic axis must also lie in this plane, and thus the morphological axis of the unpaired ray and the optic axis of the sagittal spicule are in the same plane which is at right angles to the plane of the spicule (fig. 3).

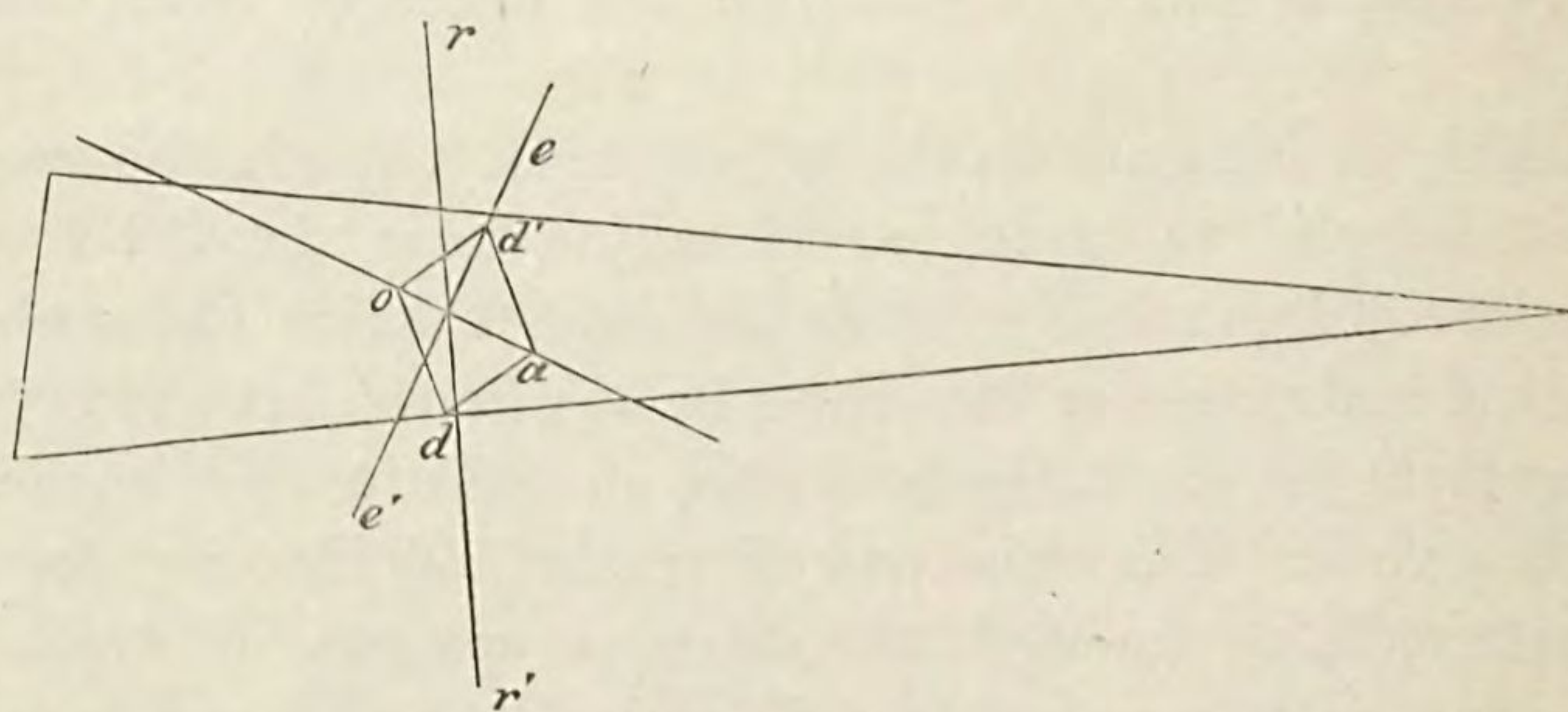


FIG. 3.

Longitudinal vertical section through the middle of an unpaired ray of a sagittal spicule, showing the position of a principal section, $o d a d'$; of the optic axis, $o a$; and an axis of maximum elasticity, $e e'$. A ray of light passing perpendicularly through the spicule is shown by $r r'$.

The spicules behave as single individuals, all parts becoming extinguished and illuminated together; so that while the optic axis

lies in the median plane of symmetry of the unpaired ray, it crosses transversely the median plane of symmetry of the paired rays, which make an angle of from 90° to 120° with the unpaired ray.

I may now allude to a curious difference between the refractive index of the triradiate and the acerate spicules of *Grantia*. The latter, as we have already stated, have a refractive index of 1.485; the former, on the other hand, disappear in balsam (*r. i.* = say 1.520 to 1.525) when viewed by the extraordinary rays which vibrate in the principal section of the analyser. Hence the axis of maximum elasticity, which lies at right angles to the optic axis in the same plane, cannot be vertical to the plane of the spicule, but is inclined from it at an angle of 55° to 60° , or at 30° to 35° from the common axis of the nicols: and the optic axis consequently makes an angle of 30° to 35° with the plane of the spicule, or of 55° to 60° with a vertical ray of light (fig. 3).

Although the triradiates and quadriradiates extinguish when one ray is parallel to either diagonal of the nicols; yet the parallelism is not always exact, the difference often amounting to 8° or 10° .

The acerates of *Grantia* extinguish at about 20° ; the angle varying about 10° , but usually much less, on each side of this. As they become invisible at this angle, when mounted in balsam and viewed by the extraordinary rays which vibrate in a plane at right angles to the principal section of the analyzer, it follows that the plane of the principal section of the analyzer then cuts the spicule transversely to its length at an angle of 70° (fig. 5); and next, that an axis of maximum elasticity at right angles to the optic axis lies vertically in the spicule, and hence that the optic axis is horizontal.

The club, or retort-shaped, spicules of *Grantia* extinguish when the long ray makes an angle of 30° with a diagonal of the nicols; the thick, short ray then extinguishes, according to the angle it makes with the long ray, at from 10° to 30° (fig. 6).

A comparison of the relations of the spicules to each other, as shown in figs. 4 to 6, will show that the acerate spicules are not homologous, as one might have suspected, with the unpaired ray of a sagittal spicule, but with one or both of the paired rays, probably with both; since in many of the sagittal spicules these rays both make an angle of almost 90° with the unpaired ray, when they are both nearly in the same straight line. The club-shaped spicule also probably corresponds to the paired rays of the sagittal. It may be that we are not justified in thus determining homologies by means

of polarised light; but this introduces questions too wide for profitable discussion in this place.

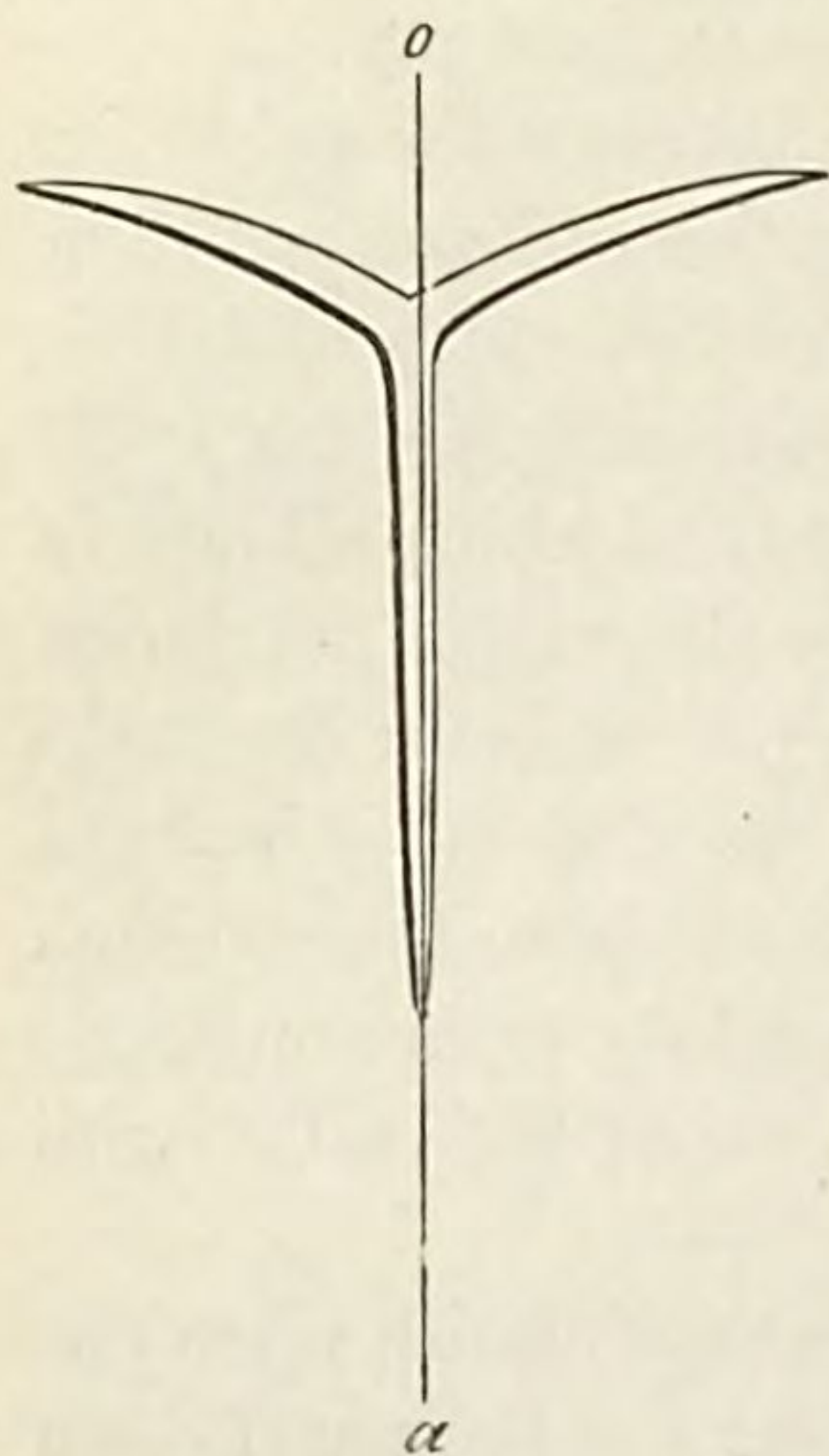


FIG. 4.

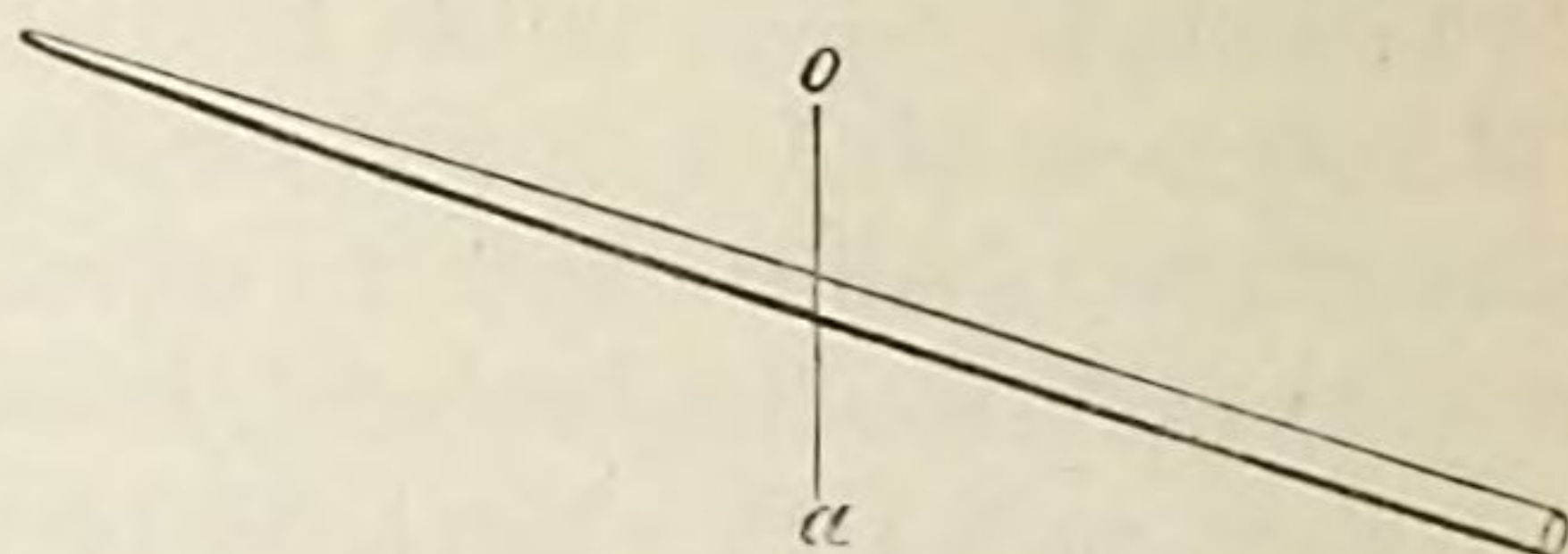


FIG. 5.

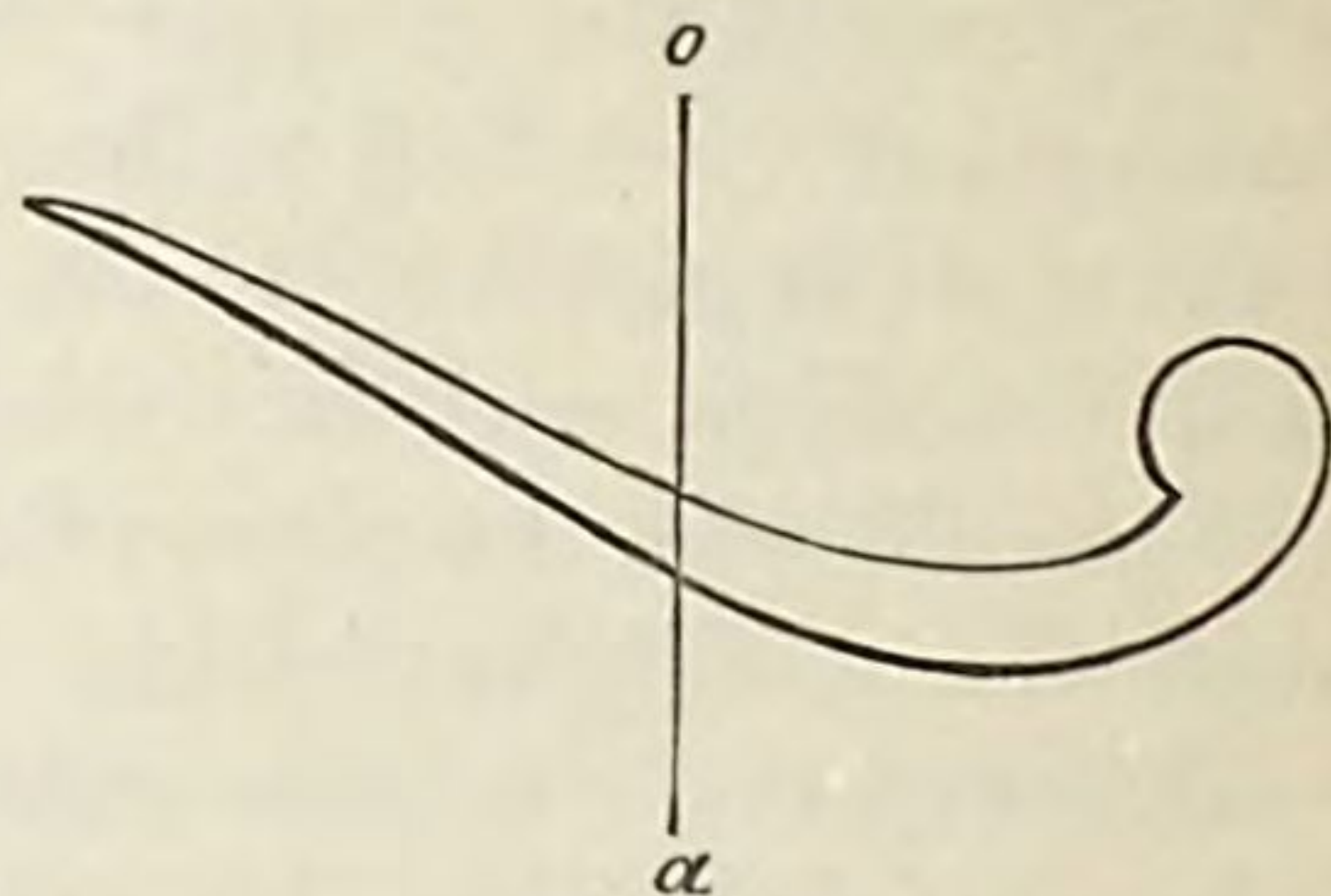


FIG. 6.

Showing the positions in which the spicules of *Grantia compressa* extinguish between crossed nicols. $o\alpha$, line of intersection of the plane of the principal section of the analyzer with the spicule: the optic axis lies in this plane.

Finding in my collection a slide on which I had mounted spicules from an unidentified calcisponge from Port Elizabeth,¹ possessing acerates of a colossal size, I turned to examine the extinction angles for these, and obtained results closely agreeing with those for *Grantia*. The sagittal spicules of this sponge are distinguished by a particularly long unpaired ray: out of 10 examples, 5 extinguished at 0° , and 5 at 10° ; the acerates extinguished at from 13° to 19° .

Etch-figures.—As these spicules had lain for some years in balsam, which is known to dissolve calcite, I expected to find etch-figures which, from the slow rate at which they would have been produced, should be neatly developed. Under a Zeiss D, and Ocular No. 4, they were easily found on both acerate and sagittal spicules. On the former they exist as parallel striæ, inclined at an apparently somewhat variable angle, often of 60° to 75° . The striæ frequently occur in groups, which terminate in many cases in a ledge transverse to them, making with them sometimes an apparent angle of

¹ In all probability this sponge is *Leuconia glomerosa* (Bwk.), P. Z. S., 1873, pt. iv., figs. 1 to 6.

about 60° to 75° , and sometimes of about 96° (Pl. XV., figs. 5 and 7). In some cases near the sharp ends of the spicules, which have been eroded to a greater depth than the thicker central part, we find projecting angles of evident crystals. These angles, which are of faces and not quoins, measure usually from 64° to 77° as projected by camera lucida on a plane surface (pl. xv., figs. 1 and 2).

The sagittal spicules display a curious difference in the distribution of erosion, interesting as showing the influence of crystalline structure on solution; their basal, or paired rays, are always well etched with striæ, and sometimes show as well a fringe of projecting angles on the distal or both margins (pl. xv., fig. 3). The unpaired ray, on the contrary, is never visibly eroded; it appears to enjoy complete immunity from the solvent power of balsam.

Wishing to develop etch-figures at will, I experimented first with *Grantia*, but found its spicules were too minute to give satisfactory results. I then managed to extract from under the cover-glass of my mounted specimen of *Leuconia glomerosa* (?) a bundle of colossal acerates; after washing the balsam away with ether they were placed in dilute acetic acid, and the process of solution watched under a Zeiss D. Striæ were soon developed similar to those produced by the balsam; the groups of striæ being margined by one of themselves, strongly developed, and truncated by a ledge which sometimes made an angle of about 77° with them, the acute angle of a face of a rhombohedron; in some cases three ridges were produced, giving a triradiate figure with angles of about 108° , 125° , and 127° : such a figure would be produced by the edges of a rhombohedron placed similar to that shown in the projection, fig. 7, p. 388, where the corresponding angles are 104° , 116° , and 140° . The large difference in these angles and those just noted is partly to be accounted for by a slight difference in the position of the two rhombohedrons, and partly by the difficulty of obtaining exact measurements of angles determined by such extremely short lines as those of the etch-figures. Partly, also, the plane on which the figures were projected by the camera lucida would not be exactly at right angles to the reflected rays of light, and some distortion is inevitable. It is clear, however, that the etch striæ are the edges of rhombohedrons, of each of which four faces, lying in a zone, are elongated to such an extent as to convert the rhombohedron into a prismatic fibre. On one side of an edge, exposed as an etch

stria, a transverse ridge corresponding to another edge of the rhombohedron would make an apparent angle of about 96° , and, on the other, another transverse ridge of 60° to 75° , as observed.

In the projection shown in fig. 7, p. 388, the edges corresponding to the truncating striæ make apparent angles of 94° and 40° with the edge which furnishes most of the striæ.

As the solution of the spicule under observation continued, a beautifully defined hollow rhombohedron made its appearance (pl. xv., fig. 11), and traces of others were seen. Finally, the spicule broke up into segments; but I was unable to determine whether these were bounded by cleavage planes.

Cleavage.—The spicules of calcisponges usually break with a conchoidal fracture; but it seemed possible that traces of cleavage might be obtained by heating the spicules to short of redness, and then plunging into water. This was tried with the coronal acerates of *Grantia ciliata*.

After igniting, the spicules are perfectly white and opaque, as seen by reflected light; mounted in glycerine, they become transparent, are brown in colour, and finely granular in texture. The edges of the spicules are broken (pl. xv., fig. 8) by straight lines, the fractures being apparently those of cleavage; cleavage planes frequently traverse the spicule, dividing it into rhomboidal fragments, and often it becomes entirely resolved in places into a collection of navicula-like bodies (pl. xv., figs 9 and 10), which appear to be rhombs with rounded edges.

Form of Transverse Section.—This experiment enabled me to definitely ascertain a fact I had long suspected, but had up to this been unable to prove: the acerates of *Grantia*, as they roll over, when seen under the microscope, appear to be greatly flattened along two opposite sides, one diameter of a transverse section being much longer than the other. So long as the spicules were transparent I was not sure that this might not be an optical delusion; now that they were opaque, when seen by reflected light, the matter could be put to a certain test, as it was, with the result of proving that these spicules are in fact, as in appearance, far from cylindrical, being greatly compressed from side to side. The colossal acerates are also of oval section, and possibly rhomboidal, the angles of the rhomb being rounded off. At all events, one which had been etched (pl. xv., fig. 7) showed, after it had broken into

fragments, such an outline. That they are not cylindrical may easily be proved by rolling them under a cover-glass, and measuring their diameter in different positions. Their optical double-sidedness, due to difference in refractive index, is also then clearly seen without the aid of polarized light.

Hæckel¹ has recognised the fact that the section of calcareous spicules is not always circular, since he says that "in the acerates, as well as in the triradiates and quadriradiates, the transverse section of the ray is usually circular, seldom elliptical, and much seldomer linear, so that the ray is flattened band-like." He gives no instances however.

Application to the Pharetrones Question.—Since the acerate spicules of some calcisponges are oval in section, or possibly rhomboidal, this enables us, when other characters are wanting, to distinguish such spicules from the similar ones of the siliceous sponges; and if the Pharetrones were originally calcareous, their colossal spicules should afford us oval and rhomboidal sections; for even if the rhomboidal outline observed in the recent spicule were due to etching, it is also true that the fossil spicules have suffered from the same cause, and so should exhibit similar outlines. On turning to my thin slices of Pharetrones I find that a rounded polygonal outline frequently characterises the sections of colossal spicules; many offer an oval section; and though, of course, a cylindrical spicule will give an oval outline if cut obliquely, yet in many cases the sides of the ellipse in the fossil spicules are far too flattened to be explained in such a manner (pl. xv., fig. 12). Though oval and polygonal outlines are common, circular ones are not absent; but that does not affect the argument, as we do not assert that cylindrical spicules do not occur among calcisponges, but that oval and polygonal ones are not known amongst the siliceous sponges.² On turning to the illustrations in my Paper on Catagma, I find that I had at that time represented the sections of these large spicules as somewhat polygonal, though I did not recognise the fact at the time, nor if I had should I have understood its significance. A distinct polygonal outline is given to the rays of many calcisponges in Hæckel's "Monograph," v., Taf. 27, &c.

¹ Hæckel, "Die Kalkschwämme," Band i. p. 203.

² The shafts of Lithistid skeletal corpuscles are, however, not always circular in section.

These observations furnish a further strong argument in favour of the originally calcareous nature of the Pharetrones.

Crystalline Structure.—We are now provided with observations sufficient to investigate more closely the crystalline structure of calcareous spicules.

Commencing with the acerate spicules, we find that in the position in which they usually rest the optic axis lies in them horizontally, inclined about 70° to their morphological axis, and that an axis of maximum elasticity at right angles to the optic axis passes through them vertically.

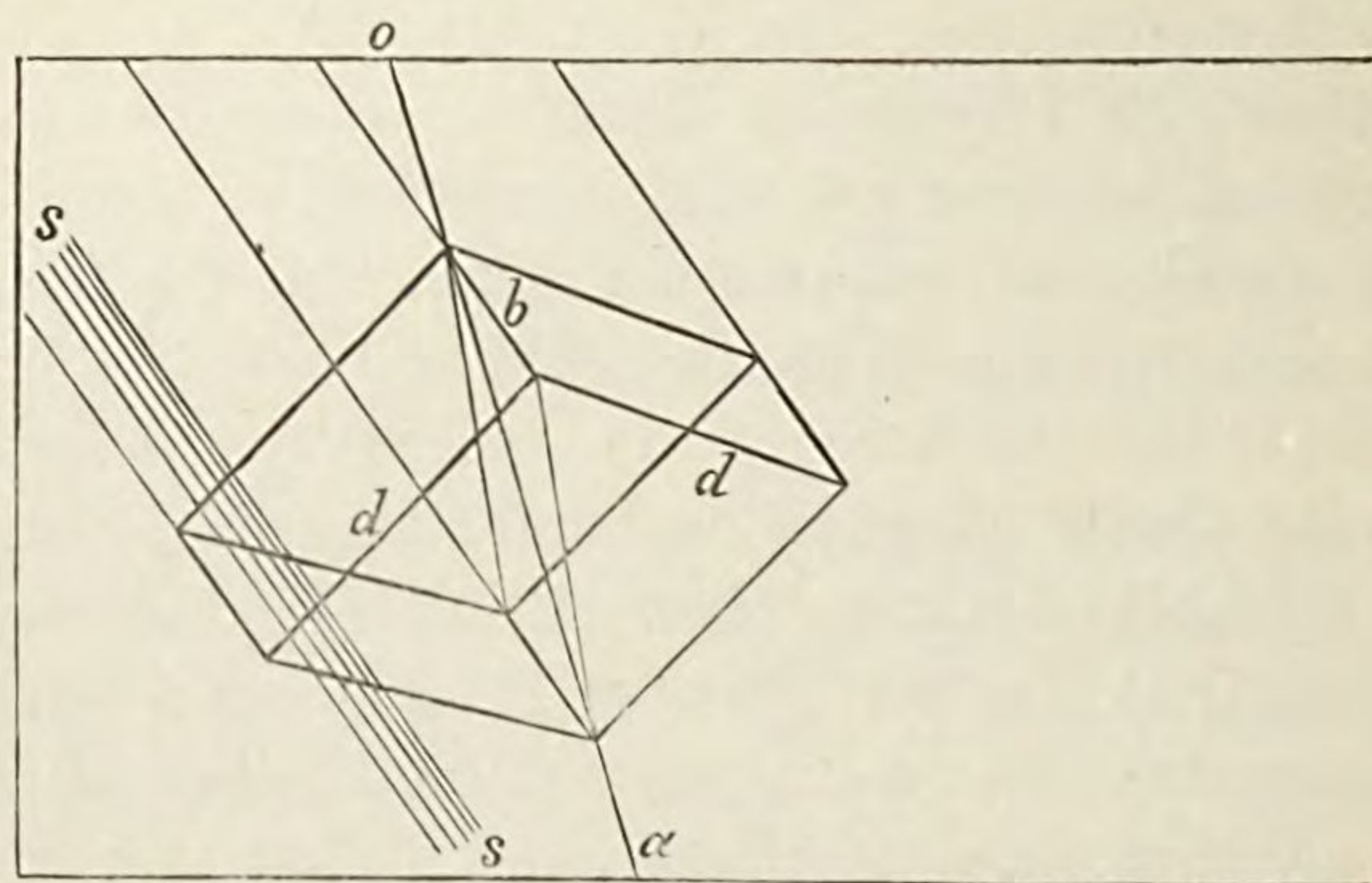


FIG. 7.

Diagram showing the position of a primitive rhombohedron, as it would be seen within an acerate spicule of a calcsponge, the optic axis being placed horizontally. *b*, polar edge; *d, d*, lateral edges of the rhombohedron; *o a*, optic axis; *s s*, direction of striæ produced by etching: they are parallel to the edges which lie in a zone with *b*.

Without spending time in discussing the various positions in which a primitive rhombohedron may be placed in order to satisfy these conditions, let us proceed at once to describe its actual relations to the spicule as deduced from a consideration of the whole of the evidence. A primitive rhombohedron lies within the spicule, so that one lateral solid angle is lowermost, and four parallel edges are inclined at an angle of about 56° with the edge of the spicule as seen through the microscope. These edges are those which give rise to the parallel striæ of the etch-figures; four other parallel edges make an angle of 22° with the spicule edge, and the remaining four parallel edges similarly make an angle of 46° . It is the last two groups of edges which give rise to the transverse striæ of the etch-figures.

The angle of extinction for the spicule will be about 20° (17° in the projection, figure 7), and for the striæ a like amount.

It is obvious that if the rhombohedron occupy this position, one will, on rolling the spicule under a cover-glass, alter the observed index of refraction and the angle of extinction.

The reason that any approach to constancy in these elements is discoverable in the spicules, as they chance to lie on the microscope slide, is due to their bow-shaped form and lateral compression, so that they rest most readily on one side; and the fact that, under these circumstances, a close approximation to constancy occurs, shows that the crystalline structure of the spicule is related in a more or less constant manner to its form.

On rolling the acerate spicules of *Grantia* and those of *Leuconia glomerosa* (?) under a cover-glass, the expected changes were observed; the refractive index varying from about its minimum to about its maximum value for the extraordinary rays, and the angle of extinction from 0° to 44° . In some positions the colossal spicules gave a refractive index similar to that of the sagittal triradiates, *i. e.* they vanished in balsam; the striæ should then extinguish at 0° , and make an angle of 75° with the edge of the spicule, which should consequently extinguish at 15° . These conditions were found on measurement to be rigorously fulfilled.

We may fairly conclude, then, that the acerate spicules of those calcispongiæ examined are built up of excessively elongated primitive rhombohedrons of calcite, which lie with the optic axis inclined at about 75° to the morphological axis of the spicule.

That this result holds good not only in spicules which have been treated with acid, but in unaltered spicules taken from spirit specimens (and we may infer in living examples), is shown by the similar behaviour of both when examined with polarized light.

The position of the rhombohedron relative to the surface of the spicules is very similar to that which may be observed in rhombohedra of calcite filling up a cavity within a limestone rock, or inside the chamber of an ammonite; and we may suppose that the deposition of calcite within the spicule sheath occurred according to just the same laws as those which are followed in the purely mineral world; the first formed layer of minute rhombohedra

would govern the position of the crystalline axes of all the rest, and as growth took place by apposition, all subsequently deposited rhombohedra would be arranged in perfect conformity with those which served as a foundation; and should the spicules after the death of the sponge serve as nuclei on which a further calcitic deposit was laid down, the crystals of this would be governed in their arrangement by that already existing in the spicules.¹ Hence, in fossil Pharetrones we should expect to find just the same optical characters as those observed in the recent calcispongiæ.

Foraminifera.—Dr. Sorby² states that from the nature of the case he was unable to determine the specific gravity of Foraminifera; but with true insight he inferred that they consist of calcite and not of aragonite. Dr. Sorby, no doubt, had in mind the Perforate group of foraminifera; and I find by my method of using Sonstadt's solution under the microscope, that these have a specific gravity of from 2.626 to 2.674. The forms I examined comprised Globigerina, Textularia, Rotalia, Discorbina, Nodosaria, Nonionina, and Lagenæ. They could be clearly seen under the microscope floating free from air and other impurities in the Sonstadt solution, so that had it been desired I could have taken the specific gravity of any single one. I also obtained the specific gravity of Polytrema; it is the same as that of quartz (2.65). In the majority of the Perforate foraminifera the specific gravity is from 2.65 to 2.674; they evidently consist of calcite, and the difference in specific gravity may be attributed to the presence of organic matter, of which it would require 3.3 per cent. at a specific gravity of 1.5, to reduce the specific gravity of the foraminiferal test from 2.7 to 2.66. The Imperforate foraminifera are denser than the Perforate forms. I examined Milliola, Peneroplis, Spirolina, and Orbiculina. Their specific gravity ranged from 2.7 to 2.722; and as they contain a large quantity of organic matter, easily seen as a thin film when the mineral matter is dissolved away with acids, the specific gravity of the mineral part of their tests must be higher

¹ This prediction has since been unexpectedly verified. Some calcareous spicules, left to stand in water containing carbonate of lime, have become overgrown with crystals of calcite, arranged in accordance with the crystalline structure of the spicule, as ascertained above.

² Sorby, "Presidential Address on Limestone," Quart. Jour. Geol. Soc., 1879.

than that of calcite. Either it consists of aragonite, or, if of calcite, some other substance must be present in addition, possibly iron carbonate or phosphate of lime. It would require 12.5 per cent. of organic matter to reduce the specific gravity of this foraminifera from 2.9 (that of aragonite) to 2.725, and 14.37 per cent. to 2.7, the specific gravity which most of them possess.

Although sufficiently common in the tertiary rocks, Imperforate foraminifera are much rarer than the Perforate in older deposits, and this comparative rarity would be consistent with an aragonite constitution for their tests.

Dr. Carpenter¹ states that the shells of the Imperforata have no structure of any kind. I find, however, that the shell of *Milliola*, when viewed mounted in turpentine with transmitted light, has a very finely granular structure, minute granules lying thickly and evenly scattered in the transparent amber matrix.

NOTE ADDED IN THE PRESS.

In order to make quite sure that the outline of the transverse section of the acerate spicules in some species of calcareous sponges is otherwise than circular, I prepared thin slices of entire specimens of a species of *Grantia* from Vancouver's Land (*Grantia coronata*?) by cutting in frozen jelly. The illustration (pl. xv., fig. 13) shows a section through the "neck" of the sponge; the coronal spicules are arranged in concentric circular rows (arcs of nine rows out of sixteen visible are represented in the figure), and the transverse section of each is an ellipse with flattened sides, or an oblong with rounded ends. Certain larger acerates of the radial tubes (pl. xv., fig. 14) offer polygonal outlines, like those of the *Pharetrones* (pl. xv., fig. 12). These sections obtained from spicules, unaltered in any way by treatment, dispose of all doubt as to their form; and since the acerate spicules of three species of *Calcispongiæ*, all that I have examined, give similar results, it would appear that a circular outline is much less common among the acerates of this group than has been hitherto supposed. It would appear that the form is influenced by the mineral composition, and if so, one might expect calcareous spicules to rarely exhibit quite circular outlines: other duties, however, prevent my extending my observations in this direction.

¹ Carpenter, *Introduction to the Study of the Foraminifera*, p. 44.

DESCRIPTION OF PLATE XV.

Fig. 1.—Colossal acerate spicule of *Leuconia glomerosa* (?) (Bwk.), showing faces of rhombohedra, revealed by erosion; from a portion near the point.

Fig. 2.—Similar, showing the eroded pointed end of the spicule.

Fig. 3.—Two sagittal spicules from the same sponge, showing the eroded paired rays, which are both striated and margined by rhombohedral faces; and the unpaired ray which presents no signs of erosion.

Fig. 4.—Part of an eroded acerate, showing striæ on one side, and rhombohedral angles on the other. On one of these angles a rhombohedron has been indicated by dotted lines, to show the relation of the striæ and the angles, and the probable position of the rhombohedron relative to the spicule. The apical angles of the rhombohedron have been joined by a dotted line, *o a*, which, prolonged in both directions, indicates the position of the optic axis. This makes an angle of about 72° with the edge of the spicule, which should therefore extinguish at 20° . The striæ make an angle of about 65° , and should extinguish at 7° . This approximates to an observation made, where the striæ made an angle of 66° with the edge of the spicule, which extinguished at 15° , the striæ at 9° .

Fig. 5.—Part of a colossal acerate, showing etch striæ.

Fig. 6.—Transverse section of a colossal acerate, which had been slightly etched by acetic acid.

Fig. 7.—A group of etch striæ.

Figs. 8 and 8A.—Two of the coronal acerates of *Grantia ciliata*, after heating nearly to redness, showing broken edges, bounded by cleavage planes.

Fig. 9.—Similar, showing the navicula-like bodies into which the spicule breaks up.

Fig. 10.—A single one of these rhombs.

Fig. 11.—A colossal acerate, after etching with acetic acid, showing groups of striæ, and on the right-hand edge below three sides of a rhombohedral pit. On the right-hand side above is a triradiate marking, corresponding to the edges *b*, *d*, and *d'* in the projection, fig. 7, woodcut, p. 388.

Fig. 12.—Outlines of transverse sections of shafts of colossal spicules in a Pharetrone (*Catagma porcatum*).

Fig. 13.—Part of transverse section through the 'neck' of *Grantia* sp. from Vancouver, N. America, showing arcs of nine out of sixteen circular rows of acerate spicules visible in the preparation.

Fig. 14.—Transverse sections through large acerate spicules of the same sponge.

Fig. 15.—Transverse sections of acerate spicules shown in fig. 13 more highly magnified: (*a*) sections at right angles to the lines of sight; (*b*) slightly inclined, showing the side of the spicule, indicated by shading.

All figures drawn by Camera lucida, figs. 1 to 12 under; Zeiss D, Oc. No. 4; figs. 13 and 14, Zeiss D, Oc. No. 2; fig. 15, Zeiss E, Oc. No. 3.

XLVIII.—ON THE NEWLY DISCOVERED SAPPHIRE MINES
IN THE HIMALAYAS.¹ BY V. BALL, M.A., F.R.S.,
Director, Science and Art Museum.

[Read, February 16, 1885.]

A VERY remarkable, and so far as is known, new discovery of a mine of sapphires, rubies, and ordinary corundum was made about the years 1879 and 1880, in the district of Paldar, or Padar, north of the Chandrabagha Range, but south of the main chain of the Himalayas. The district of Zaskar—whence they were incorrectly supposed to come by some writers—lies to the north of the chain.

The stones were found at the foot of a precipice, where a landslide had taken place. The including rocks are gneiss and mica schist. At first the stones were merely collected by the villagers, who were attracted by their beautiful colours; but so little was their value realized, that they were used as flints are for striking lights with steel. At that time they appear to have been so abundant that one writer speaks of having seen about one cwt. of them in the possession of a native. Gradually, as they were carried by traders to distant points, especially to Simla, their value became known, and the agents of jewellers commenced a brisk competition, till most of the available stones had been bought up. The Maharajah of Cashmere then intervened by sending a regiment of sepoy, with their officers, to take possession of the mines; and, it would appear, with *carte blanche* to harry the inhabitants who had, or who were suspected of having, any of the stones in their possession. Indeed, so thoroughly did they fulfil their mission, that any one they laid hands upon who was found to have money, was suspected of either having sold or being about to purchase sapphires, was thereupon despoiled, and if not arrested and confined, was placed under observation.

¹ The principal authorities on the subject are—Mallet, Rec. Geol. Surv., India, vol. xv., 1882, p. 138; S. B. L., *Civil and Military Gazette*, Lahore, Nov. 2, 1883; Shepard, C. V., Am. Jour. Sci. (vol. xxvi., No. 155), Nov. 1883, p. 339; Lydekker, R., Mem. Geol. Surv. India, vol. xxii., p. 335.

The effect, as described by the few Europeans, principally missionaries,¹ who live in the country, has been to cause those who knew, or thought they knew, other localities where similar stones were to be found to remain silent, and to conceal evidence of their knowledge so as to escape oppression.

Many of the specimens which have been examined are well-formed double hexagonal pyramids; their surfaces are often much covered with small crystals of tourmaline, which also penetrate the mass. A thin coating of a white mineral, supposed to be *gibbsite*, occurs on some of the specimens; and chlorite also occurs with the sapphires, besides other varieties of corundum and magnetite. Since corundum in various forms is a known product of many parts of the peninsula of India, and is mined for, and has a commercial value with the natives,² it is not improbable that sapphires have been occasionally met with; one, for instance, which is mentioned in books on precious stones as "the wooden-spoon seller's sapphire," is said to have been found in Bengal; but I have been unable to find any definite record of a sapphire mine in that country. Like other jewels, sapphires have been always abundant in the Indian marts since the earliest times, when they were known to Europeans as hyacinths, a name derived from the Arabic and Persian *yacut*. The term was also applied to a variety of garnet; but the evidence distinctly points to their having been imported from Ceylon, and to a small extent from Burmah. It is noteworthy, as regards the latter country, that sapphires occur as sparingly in the Kyatpen (often incorrectly written Capellan) ruby mines as rubies do in the Cingalese sapphire mines.

The above abstract of information regarding these mines was prepared some time ago, and it is now communicated to the Society in consequence of a recent acquisition by the Museum of one fine specimen, and some smaller fragments. They were brought to Mr. Moss by a gentleman, who informed him that they were a remnant of a large quantity purchased from a native, who came from a locality situated about 150 miles north of Simla. The locality mentioned above is much further away; but the discrepancy is of

¹ Rev. A. W. Heyde, Rev. M. B. Carleton, W. Graham, formerly of Kulu, and a writer in the Lahore paper, signing himself S. B. L.

² I was recently told by Dr. Isaac Lea, of Philadelphia, that some considerable shipments of Indian corundum had been received there.

no importance, as there was no pretension of exact accuracy in the statement. We may safely conclude, I think, that the specimen now exhibited is from Paldar. It is a slightly distorted double hexagonal pyramid, weighing 126·425 grammes, and measuring 2·25 in. in length, by 1·8 in maximum breadth; the sp. g. is 3·98. Before the apices of the pyramids were broken off it may have been longer. In colour it is somewhat mottled, the blue being irregularly suffused through the greyish white of the bulk of the stone. Where broken it presents a somewhat opalescent appearance, and this indeed, it is stated, was the cause of its mutilation, as its former possessor was told by some one that if he broke it he would find opal inside. Fortunately the ignorant advice so offered was only partially acted upon, and this interesting specimen will be preserved in our mineralogical collection. It is certain that, even if it does not contain portions of perfect and uniform colour, it is still such a stone as the astute jewellers of Ceylon would value for cutting. I have several stones cut by these adepts, which when looked at in their setting, present a very good colour, owing to the ingenious way in which the blue portion of an otherwise colourless stone has been manipulated so as to form a back.

XLIX.—A NEW SPECIES OF HALCAMP (H. ANDRESII)
FROM MALAHIDE. BY ALFRED C. HADDON, M.A.,
F.Z.S., Professor of Zoology, Royal College of Science,
Dublin. (PLATE XVI.)

[Read, November 17, 1884.]

***Halcompa andresii* (sp. nov.).**

DESCRIPTION.

Form.—Column divided into capitulum, scapus, and physa. Capitulum and scapus slightly corrugated. Physa a distinct rounded bladder, may become flaccid, but is non-retractile, with numerous suckers. Tentacles 12, marginal, monocyclic, cylindrical, obtuse, slightly arched upwards, about as long as the diameter of the disc. Disc round and flat, central portion often elevated into a truncated cone. Mouth linear.

Colour.—Capitulum pale burnt-sienna colour, with a pair of sulphur-coloured bracket-shaped () marks in the inter-radii. Scapus translucent, through the walls of which the generative organs (?) shine with a creamy orange colour. Physa transparent white, with opaque white suckers. Throughout the whole length of the column the insertions of the mesenteries appear as white lines. Tentacles of same colour as capitulum, but more transparent, with four madder-brown rings on the internal aspect, of which the two lower are usually V-shaped; on the outer aspect of the base of each tentacle is a pair of slightly diverging brown lines. Disc of same colour as tentacles, with 12 inter-radial sulphur-coloured lines, extending from the mouth to near the base of the tentacles where they become brown in colour; near the base of each tentacle is an imperfect madder-brown oval ring, bounded externally by a sulphur-coloured streak; there is a second similar streak below the lowermost tentacular ring. Mouth pale orange.

Dimensions.—Length about 20 mm.; diameter about 4.5 mm.

Habitat.—In sand, at Malahide, county Dublin, at low water.

This is the first recorded example of this genus in Ireland; it was found on the shore at Malahide at low water by my friend and former pupil, Miss A. Shannon, on September 13, 1883.

Like the other species of the genus, this form usually lies buried in the sand; when free, it often adheres by its posterior extremity, standing upright in the water, or it may lie prostrate, adhering by some of the small wart-like suckers of its physa.

I give myself the pleasure of naming this species after my learned and laborious friend, Dr. A. Andres, Professor of Zoology at Milan, to whom all zoologists are indebted for his most admirable Monograph on the Actiniæ.

The type specimen is deposited in the Natural History Museum, Science and Art Department, Dublin.

Two species of *Halcampa* have been previously recorded as British, viz. *H. chrysanthellum* (Peach), and *H. microps* (Gosse); the former from Cornwall, and the latter from South Devon. The name of the first species stands; but, as Andres has shown in his Monograph of the Actiniæ,¹ *H. microps*, possessing as it does sixteen tentacles, is undoubtedly an *Edwardsia*, and therefore does not concern us at present.

ANALYSIS OF THE BRITISH SPECIES OF HALCAMP.

Tentacles with six white half-rings. Disc bluish in centre, brown towards periphery, with pale inter-radial lines, which are trifid towards the base of the tentacles.—*H. chrysanthellum* (Peach).²

Tentacles with four brown half-rings. Disc uniform; buff, with yellow inter-radial lines, and an oval brown ring at the base of each tentacle.—*H. andresii* (sp. n.).

Dr. W. Keferstein described, in June, 1862,³ two kinds of

¹ Fauna und Flora des Golfes von Neapel, IX. Die Actinien, 1884.

² Cf. Actinologia Britannica, a History of the British Sea-anemones and Corals, 1860, p. 247.

³ Zeitschrift für wissenschaftliche Zoologie, XII. (1863), pp. 31–34, Pl. II. figs. 15–22.

Halcompa from St. Vaast la Hougue, Manche (North France), which he named *Xanthiopus bilateralis* and *X. vittatus*, *gen. et sp. nov.* Andres considers these as varieties of one species, which he re-names *Halcompa kefersteini*, var. *a. vittata*, and var. *β. bilateralis* (*l. c.*, p. 102).

Keferstein's description is very meagre, and his figures imperfect; but there can be no doubt that the French species is distinct from the Irish.

EXPLANATION OF PLATE XVI.

***Halcompa andresii* (sp. nov.).**

Fig. 1.—Side view of animal $\times 3$ diam.

„ 2.—Side view of disc and mouth, showing the tentacles in their ordinary position $\times 4$ diam. about.

„ 3.—View of disc and tentacles from above $\times 4$ diam. about.

„ 4.—Side view of external aspect of tentacles $\times 4$ diam. about.

L.—THE STRUCTURE AND HABITS OF *PEACHIA HASTATA* (GOSSE), PART I. BY ALFRED C. HADDON, M. A., Professor of Zoology, Royal College of Science; and GEO. Y. DIXON, M.A. (PLATES XVI., XVII., and XVIII.)

(Read, December 15, 1884.)

***Peachia hastata* (Gosse).**

HISTORICAL.

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|-----------------------------|---|---|
| <i>Actinia cylindrica</i> , | . | Reid, 1848, <i>Ann. Mag. Nat. Hist.</i> , n.s., i.,
p. 34, Pl. (<i>non</i> Renier). |
| <i>Peachia hastata</i> , | . | Gosse, 1855, <i>Trans. Linn. Soc.</i> , xxi., p. 267,
Pl. XXVIII. |
| „ „ | . | Gosse, 1855, <i>Man. Marine Zool.</i> , i., p. 31,
fig. 46. |
| „ „ | . | Milne-Edwards, 1857, <i>Hist. Nat. des Coral-
liaires</i> , i., p. 287. |
| „ „ | . | Gosse, 1858, <i>Ann. Mag. Nat. Hist.</i> , ser. 3,
i., p. 418. |
| „ „ | . | Holdsworth, 1859, <i>Ann. Mag. Nat. Hist.</i> ,
ser. 3, iii., p. 78. |
| „ „ | . | Gosse, 1860, <i>Actinologia Britannica</i> , p. 235,
Pl. VIII., fig. 3, and woodcut. |
| „ „ | . | Hincks, 1861, <i>Ann. Mag. Nat. Hist.</i> , ser. 3,
viii., p. 363. |
| „ „ | . | Dana, 1872, <i>Corals and Coral Islands</i> , p. 25
and p. 26, fig. 1. |
| „ „ | . | M'Intosh, 1874, <i>Ann. Mag. Nat. Hist.</i> , ser. 4,
xiii., p. 220, |
| „ „ | . | Faurot, 1884, <i>Comptes rendus</i> , xcvi. No.
12, p. 756. |
| <i>Siphonactinia</i> , „ | . | Andres, 1884, <i>Die Actinien</i> , Fauna u. Fl.,
d. Golfes, v. Neapel, ix., p. 110. |

THIS remarkable species has hitherto only been recorded from Torbay (S. Devon), “at extreme low water, and thence downwards, buried in sand”—Gosse; from St. Andrew's Bay (Fife)—Reid; “thrown ashore on the West Sands after storms in great

numbers. It occurs also in the stomach of the cod"—M'Intosh; and from Roscoff (Côtes du Nord, N. France)—Faurot. We now extend its range to Dollymount, Dublin Bay, and from information received from Miss Shannon, it is probable that it also occurs at Larne, county Antrim; it therefore is distributed over the British Isles, and to the north of France. The peculiar habits of this form have probably been the reason why it has not been met with elsewhere, and more often.

Mr. Gosse, on p. 245 of the *Actinologia*, says of the *Actinia cylindrica*, described by Reid:—"It must have certainly been a *Peachia*, and may possibly have been an immature *P. hastata*." Gosse states three points in which it disagreed from his species:—" (1) It was but one and a quarter inch long." This objection amounts to nothing. " (2) The conchular lobes were *twelve*, six of which were very minute, *triangular, orange*, with translucent edges." As will be seen from our account, the conchular papillæ are subject to great variation in number, size, and colour. " (3) Twelve bands of faint reddish-brown radiated across the disk." From this it would appear that Dr. Reid's specimen was sickly, having been "thrown on shore by a storm," and that it never properly expanded, consequently the disc would not be seen. The tumid striped œsophagus of this form is so large and so frequently protruded, and especially when the animal is dying, that there can be little doubt that it was in this instance mistaken for the disc. Thus none of Gosse's objections stand. Reid describes "the upper three-fourths of the body to be opaque and of a pale pink colour." In one of our specimens the column, excluding the physa, was of an opaque flesh-colour, with only one or two fine reddish-brown stripes or spots.

The identity of these two species is admitted by Dr. W. C. M'Intosh, who after recording it from St. Andrews, states (*l. c.*, p. 220) it "was thus first found in Britain by Dr. John Reid, of St. Andrews, who published a description of his single example in 1848 (*Physiological, Anat., and Pathol. Observations*, p. 656, pl. 5, f. 21 and 22); his title (*A. cylindrica*) has, therefore, a prior claim to that of Mr. Gosse."

We have entered thus fully into a discussion on Reid's species, as it is more satisfactory to clear up the older species than to leave them as *dubiæ*. Although ourselves convinced of the identity of

the two species in question, we do not propose to alter the specific name which is in general use, as the name *Actinia cylindrica* was pre-occupied by Renier in 1804 (*Prodromo di osservazioni sopra alcuni animali*, p. 23), and though not now retained in use, being synonymous with *Cerianthus membranaceus*, Spallanzani, 1784, this priority is sufficient to prevent the adoption of Reid's specific name. Furthermore, Reid's description and figures are meagre and unsatisfactory, whereas Gosse's account and drawings are sufficiently lucid to enable one to readily identify the animal.

There is no doubt that Gosse has priority in the generic name, therefore we cannot follow Andres in calling it *Siphonactinia hastata*.¹

DESCRIPTION.

Form.—Column only divided into capitulum, scapus, and physa, when fully distended. When contracted the column is rugose, but smooth when fully distended; it is furnished with numerous minute suckers. The physa is very variable in size and completely retractile. Tentacles, twelve marginal, monocyclic, cylindrical, obtuse; when the animal is free they are usually carried more or less bent forwards; when in its burrow, they lie at about right angles to its length. Disc round, narrow, flat. Mouth large, but usually masked by the conchula. Conchula (the free oval extremity of the siphonoglyphe) varies greatly in complexity, having from six to twenty lobes; one basal and two lateral lobes may always be detected, which are larger and carry more secondary lobes than the remainder. The basal lobe forms a kind of lid or operculum to the siphonoglyphe.

Colour.—Capitulum translucent, the œsophagus shining through with a purplish colour. When the animal is in its burrow the contracted capitulum has a corrugated greyish appearance. When the tentacles are completely contracted, radiating white linear spots are plainly seen on the capitulum; the fundamental number is twelve, but there is a tendency for them to become

¹ *Peachia*, Gosse, 1855, *Trans. Linn. Soc.*, xxi. p. 267; *Siphonactinia*, Danielssen and Koren, 1856, *Fauna litt. Norvegiæ*, ii., p. 87; *cf.* *Ann. Mag. Nat. Hist.* (2), xx. 1857, p. 240.

more numerous. Scapus, opaque when contracted, translucent when fully distended; flesh- or almost salmon-colour, sometimes very sparsely, usually considerably splashed with reddish-brown in irregular longitudinal lines, often interrupted, and ending in streaks; some specimens incline to brownish tinge, others chestnut, and some are pinkish. Physa, translucent when expanded, tinted with the ground colour of the scapus. Throughout the whole column the insertions of the mesenteries appear as white lines, which are, however, indistinguishable in the contracted scapus; posteriorly their number is increased by the occurrence of intermediate ones. Tentacles translucent, pinkish, or very pale purplish-brown; at the base is a white W mark; above this a white equi-limbed cross, of which the arms are curved upwards. The space between these two markings is filled up with dark-brown; above are two white W marks, and frequently a third, but more faint and imperfect. The lateral bays of these W marks are occupied by a brown stripe, and are the only apparent markings under certain aspects of the tentacles—sometimes a whitish streak may be detected near the tip. The back of each tentacle bears an opaque white spot about half way between the base and the tip. Disc pinkish, with white inter-radial lines; in the radii, at the lips of the mouth, is a white spot; above that a triangular brown spot; outside this a white Λ mark, and between this and the W at the base of the tentacles is a brown $\bowtie$, or hour-glass mark. Inside of œsophagus, marked with twelve dark-brown bands, alternated with broader orange-buff bands; deeper down the colour is reddish or purple. Conchula flesh-coloured, or pale pink; aperture appears black; lobes with a brown or dark-red core, usually with a white apical spot, which may be prolonged into a white line, which appears to connect the papillæ with one another.

The markings on the disk and tentacles vary greatly in form and intensity, according to the degree to which the animal may be distended.

Dimensions.—Length, 1 to 4 inches (25 to 100 mm.) when contracted; may reach 8 inches (205 mm.) when fully distended; diameter about $\frac{1}{2}$ -inch (12 mm.) whether contracted or distended.

Habitat.—In sand at extreme low water, and at shallow depths. Localities, N. France, S. England, E. Ireland, and E. Scotland.

The appearance of the conchula has not been described by

Gosse with sufficient minuteness, we therefore deem it advisable to add a few words on the subject. The anatomical relations of this organ we reserve for our second communication; suffice it now to state that it is situated at one extremity of the mouth, and that it is manifestly formed by two folds uniting with each other, the line of junction being towards the mouth, and opposite the side we term the base. The free edge of the tube thus formed is prolonged into a number of processes—from six to twenty. The simplest state we have seen is that shown in Pl. XVI., fig. 5, where there are six nearly equal lobes—in all other specimens the basal and both terminal lateral lobes are larger and more complex than the others. They, and more especially the two latter, may give rise to several secondary processes, till the organ attains a very complicated appearance. It appears to us not improbable that there are but really three primary lobes, and that the varying number of processes may be but complications of the same. As has been already noted above, there is a dark central core; a white streak may usually be traced running from one papilla to another, and terminating at the apex of each. This organ is very extensile, and admits varied movements both as a whole and in its parts.

The observation of the physa in living specimens is rendered very difficult by its being almost always more or less introverted.

When it is fully distended a number of apparent perforations may be seen ranged in linear series along the radii, they do not extend to the scapus; no posterior pore appears to be present during full distension.

When in a state of partial distension the introverted base appears perforated; but this may be an optical delusion, as may also the above-mentioned thin spots, which are slit-like, or round, according to the amount of distension of the physa. (Pl. XVIII., figs. 3 and 4).

HABITS.

Peachia hastata makes for itself a burrow in the sand eight or nine inches deep. Sometimes it extends itself perpendicularly from this hole to a height of three or four inches, but usually it spreads its tentacles just over the surface of the sand, and it may often be seen with its tentacles withdrawn while the conchula is still protruded level with the top of its hole. When left dry by

the tide it habitually protrudes its mouth, the purplish œsophagus marked with the pale lines being then very conspicuous. Sometimes when it projects perpendicularly out of the hole it encircles itself with a collar about one inch in depth of slime set thickly with particles of sand. It rarely projects much except at night, generally sinking down if exposed to a strong light. It can make a burrow in the sand with considerable ease. Mr. Holdsworth has made an interesting observation on this process:—"After it had selected a suitable place for burrowing, in the darkest part of the vase, the posterior extremity became tapered to a fine point by a partial expulsion of the contained water, and at the same time turned downwards and pressed slightly into the ground; the fluid contents of the animal were then forced back until the base was completely distended, and by this means a shallow depression in the sand produced; the tail then resumed its conical shape, was again thrust into the ground, and swelled out; and these proceedings were continued until a hole was made sufficiently large to admit the animal. Its first efforts in burrowing had but little effect, and it was only after an hour's labour, when the cavity had become large enough to allow the polype to work in an upright position, and with the assistance of its whole weight, that rapid progress was made."¹ (See Pl. XVIII., fig. 7.)

This anemone can swallow a good-sized piece of food if it is placed on its disc. It opens its mouth slowly to the size required, and as soon as the lip grasps the food all round, it suddenly closes in upon it, swallowing down the food with more ease and rapidity than most other anemones, and often without the aid of its tentacles at all. In a few hours afterwards the digested food is vomited up by the mouth; but this is not the only mode of getting rid of its food after digestion which *P. hastata* possesses, as small portions of excrement, moulded apparently by passing through the tube, are often ejected through the conchula. When the animal is irritated, or contracts itself suddenly, three or four such pieces are sometimes ejected; but otherwise they come up at intervals, and generally a day or two after feeding. The conchula is often covered with a glairy slime which it seems to exude.

The tentacles are capable of a great amount of individual

¹ Holdsworth, Annals, N. H., for Jan. 1859, p. 78.

motion; it is not uncommon to see one or two contracted and reduced to the size of mere warts, while the rest are fully extended and ready to grasp anything that comes within their reach. They do not seem to be provided with urticating powers to the same extent as the tentacles of other anemones; for shrimps and little fish that haunt flat sands brush against, and even rest upon them, without suffering any apparent inconvenience.

In confinement we have found *P. hastata* lives best without having sand to burrow in. They generally lie at the bottom of the tank, surrounded more or less with collars of slime interwoven with the confervoid growth that gathers in an aquarium; sometimes they hold themselves erect.

The body wall of *P. hastata* is studded with minute suckers which enable it to hold itself upright against any smooth surface; these suckers never lay hold of particles of sand or shell, as do those of *Tealia* and *Heliactis*.

After being some time in confinement, these anemones often become ruptured in several places, their craspeda protruding in convoluted masses which usually slough off; the animal generally remains constricted at the point of rupture, and will live several days in this state and may ultimately recover. We have no particulars to give concerning their method of reproduction.

[*For* DESCRIPTION OF PLATES, *see over*.

EXPLANATION OF PLATES XVI., XVII., AND XVIII.

***Peachia hastata* (Gosse).**

PLATE XVI.

Fig. 5.—Upper view of conchula with six simple lobes ; same specimen as Pl. XVII., fig. 2.

„ 6 and 7.—Upper views of more complex conchulæ.

„ 8.—Side view of a complex conchula.

[All the above are greatly enlarged and not drawn to scale.]

PLATE XVII.

Fig. 1.—Side view of animal in an ordinary position ; natural size.

„ 2.—Diagrammatic view of tentacles and conchula.—G. Y. D.

„ 3.—Appearance of *Peachia hastata* in its burrow, looking down vertically upon it ; magnified.

„ 4.—Three tentacles illustrating the different appearances due to extension, illumination, &c. ; enlarged.

„ 5.—Details of markings on a single tentacle and radius ; enlarged.

PLATE XVIII.

Fig. 1.—Animal projecting from the sand, tentacles retracted, prominent conchula, showing markings on capitulum ; enlarged.

„ 2.—Capitular markings of another specimen ; enlarged.

„ 3.—Inflated physa, with slit-like spots ; greatly magnified.

„ 4.—A still greater state of distension, with circular spots ; greatly magnified.

„ 5 and 6.—Showing variations in form ; two specimens ; natural size.

„ 7.—Illustrating the way in which the animal burrows into the sand.

LI. — ON A MODEL ILLUSTRATING SOME PROPERTIES OF
THE ETHER. BY GEORGE FRANCIS FITZGERALD, M.A.,
F.T.C.D., F.R.S.

[Read, January 19, 1885.]

THE model I have constructed consists of a series of wheels, rotating on axes fixed perpendicularly in a plane board, and connected together by indiarubber bands. The axes are fixed at the intersections of two systems of perpendicular lines, and each wheel is connected with each of its four neighbours by an indiarubber band. Thus all the wheels can rotate without any consequent straining of the system if they all rotate at the same rate. If, however, some of the wheels be rotated through a different angle from others, the indiarubber bands will be strained.

If it is desired to represent a region in which conducting matter exists, it will be represented by removing the bands from a set of wheels. Suppose the bands are removed from the regions a and b , and from the connecting line ab , we can represent the charging of these regions with opposite electricities by introducing some mechanism, by means of which the wheels on opposite sides of the line ab can be rotated in opposite directions. And now I desire to explain that I do not intend the model to illustrate at all the connexion between the ether and the matter, and indeed think it one of the advantages to be derived from studying this model that it so distinctly emphasizes the distinction between the phenomena, depending on the general properties of the ether by itself, and those depending on its connexion with matter. For instance, from this very case we are considering, we get impressed upon us that it is by means of matter only that we can get a hold on the ether so as to strain it. As I am not careful to illustrate the connexion between matter and ether, any rough method of turning the wheels so as to create the proper strain, will do well enough, as it is not the method of producing but the nature of the strain produced that I wish to study. Having once rotated these wheels, we may replace the bands along the line ab , and we have the state of the ether between two oppositely electrified bodies repre-

sented on the model. Observe that half the indiarubber bands are strained, and that in lines running round the bodies the tight side of a band is always away from one body and next the other. This represents the polarisation of the ether. Clerk-Maxwell defines polarisation as a state in which the opposite sides of each element are in opposite states. Now the opposite sides of each band are in opposite states, one side loose, the other tight; and so it can very well represent the polarised state of the ether. The displacement producing the polarisation is due to the different rotation of the wheels carrying the band causing more of the band to be at one side of the wheels than at the other: less at the tight and more at the loose side of the pair of wheels, and this represents the electric displacement producing the polarisation. The direction of this displacement is at right angles to the line of the bands that are strained, and is out from one body and in towards the other, all round. Now, one of the first things one would expect a model of the ether to represent would be the force of attraction between these two electrified bodies, and which is not represented on my model. This, however, is because this force depends entirely on the connexions between the ether and matter; and as I have already explained, this connexion is not represented on my model, and in consequence of this the attraction depending on this connexion is quite rightly not represented on my model. I may, however, be permitted to suggest a way in which my model might be modified so as to represent this force, especially as it will emphasize a point about this force that is frequently overlooked in describing electrical phenomena. This point is that the force is proportional to the square of the electric displacement, and consequently cannot be directly and simply due to it, as in ordinary solids forces are produced by displacement: for in them the force is proportional to the displacement, and not to its square. The result is that the sign of the force is independent of the sign of the displacement, and is the same whether it be positive and negative, or *vice versa*. This is a very important distinction, and is obvious when pointed out, for it is evident that it is electromotive force, and not the mechanical force, that depends on electric displacement in the same way as mechanical forces depend on displacements of solids.

Now, if the wheels over which the bands run were made of some deformable, not merely incompressible, substance, such as

indiarubber, it is evident that they would be deformed by the straining of the bands. Now, if inextensible threads were wound round them, and the ends of the threads connected respectively with the bodies *a* and *b*, it is evident that as the deformation of the circular wheels would enlarge their circumferences, these threads would tend to draw the two bodies together. Now, the shortening of the threads would be proportional to the square of the linear deformation of the wheels, and so the resulting force might represent the electrostatic attraction of the two bodies. If we consider the force that would be thus produced between two infinite planes, we see that it would be the same no matter what their distance apart so long as the polarisation is kept the same; and that consequently it will represent a force varying inversely as the square of the distance from a point. I mention this crude mechanism in order to show that it is possible to represent by mechanism the connexion between the ether and matter, and also to illustrate how electrostatic attractions depend entirely on the way the ether is connected with matter.

Let us now return to consider what other properties of the ether are represented by the model. Observe, in the first place, that during the time polarisation is taking place the wheels are rotating, and that the rate of rotation of the wheels is proportional to the rate of increase of polarisation, and that the direction of the axis of rotation is perpendicular to the direction of the displacement. We, of course, at once conclude that the magnetic force is properly represented by the rate of rotation of the wheels, and its direction by the axis of rotation. We thus see that any change of displacement produces rotation of the wheels, *i. e.* magnetic force; and we will presently see that what represents an electric current is similarly accompanied by rotation of the wheels. The momentum of the wheels while rotating represents the kinetic energy of the currents producing the magnetic force, and in the case of one current is its self-induction. Now, if we suppose something to loosen the hold of the bands on the wheels, this will represent the presence of some partially conducting matter, for evidently perfectly conducting matter must be represented by the fact that no amount of difference of rotation of neighbouring wheels, *i. e.* no amount of electric displacement can produce any polarisation, and we have represented it by removing

the bands from the wheels entirely: a conductor offering some resistance would be represented by making the bands loose. If the bands be not sufficiently tight on the wheels between a and b , they will slip if the polarisation be carried far enough; and if the kinetic be much less than the statical friction, the polarisation of the medium will suddenly disappear by the slipping of the bands, and the energy of the polarisation will be converted into heat along the line of slipping. This evidently represents a discharge between the two electrified bodies. Now, observe further that, if the resistance to discharge be very small, the momentum of the wheels will carry them beyond their position of complete depolarisation, and a series of oscillations will be set up, the polarisation alternating in opposite directions; but, of course, ultimately all the energy will disappear as heat along the line of discharge. This exactly represents the discharge between two electrified bodies. If the resistance to discharge be small enough, an oscillating discharge is produced which, however, ultimately dies away, all its energy being spent on heating the wire along which the discharge occurs. Now, observe further, the direction in which the energy of the medium flows in to the line of discharge. It comes in in the length of the indiarubber bands, *i. e.* in a direction at right angles both to the electric displacement and to the magnetic force, and it comes in at the side of the line of discharge. This is exactly what Professor Poynting has lately shown to be the case in the ether.

Let us now consider the case of a complete conducting circuit in which there exists an electromotive force at one place, and resistances all round. This can be represented by taking away the bands, or making them loose, along a series of wheels in a circuit, and arranging mechanism for turning the wheels at one part of this circuit, and introducing some friction at all the other parts. Suppose our electromotive force is along the line $a b$, and that the resistance is introduced by friction along the outside wheels. As I have already explained that I do not intend my model to illustrate the action between matter and ether, any crude mechanism suffices to represent the electromotive force. The circuit where there are no bands, or loose ones, is our conducting circuit, and the friction to the wheels along it is the resistance of the circuit. Now, if the wheels be driven at any point of the circuit, all the region will be full of wheels turning, for all the

wheels must turn simultaneously. This rotation of the wheels represents the magnetic force, and the motion of the parts of the wheels in contact with the circuit being everywhere in the same direction round it, represents the electric current. There is no transference of anything along the current, and the energy developed at any point is transferred to that point, not along the current, but in at its side in the direction of the elastic bands perpendicular to the current. Now, this is exactly the state of affairs that Professor Poynting showed to exist in an electric current. This direction is at right angles to the axis of rotation of the wheels, and also to the direction of polarisation of the bands, *i. e.* to the magnetic and electric displacements. The self-induction of this circuit is represented by the momentum of the wheels. It is easy to see how the polarisation of the bands is connected with the resistance along any length of the circuit. When the resistance is great the bands will be greatly polarised, *i. e.* the electric displacement is great, *i. e.* the rate of fall of potential will be great; and as this will be directly proportional to the resistance, we see that the fall of potential along any length of the circuit is proportional to the resistance of that section, which is Ohm's Law. In order completely to represent Ohm's Law, it would be necessary to arrange that the friction was proportional to the rate of revolution of the wheels. This, however, is trenching on the connexion of matter and ether. Another question, similarly circumstanced, is the mechanical force exerted on the conductor, due to a magnetic field. It is evident that the direction in which to look for a mechanism to represent this would be something depending on the centrifugal force of the rotating wheels; but I have not invented any satisfactory way of representing it. The mutual induction of currents may be exhibited by making two circuits, on one of which the current is forced, and on the other of which the bands are simply loose. Now, on starting the first circuit, the wheels outside the second all rotate the same way, which I have explained represents an electric current in it; and the wheels inside will stay unmoved until the friction of the loose bands gradually sets them in motion, and thus, after a little while, the wheels all over the region are rotating just like those anywhere else, *i. e.* those at opposite sides of the circuit are rotating in the same direction, and the current has ceased in the circuit. The oppo-

site effect will, of course, take place on stopping the primary current.

I have thus shown how the states of the ether, that Clerk-Maxwell assumes, in order to explain electrical and magnetic phenomena can be illustrated by my model. It is not difficult either to show that the energy of the ether can be represented by equations exactly the same as those by which Clerk-Maxwell expresses it. We must, however, bear in mind that my model is only a one dimensional one, and would require to be supplemented by two others in planes at right angles to itself to represent a space full of ether. To consider, then, what the energy of the electro-magnetic field become in one dimension, I will deal with the form to which I reduced it in my Paper on the "Electro-magnetic Theory of the Reflexion and Refraction of Light" (R. S. *Trans.* vol. ii. 1880). The potential energy in an isotropic medium is,

$$W = - \frac{K}{32 \pi^2} \iiint \left[\left(\frac{d\zeta}{dy} - \frac{d\eta}{dz} \right)^2 + \left(\frac{d\xi}{dz} - \frac{d\zeta}{dx} \right)^2 + \left(\frac{d\eta}{dx} - \frac{d\xi}{dy} \right)^2 \right] dx dy dz ;$$

while the kinetic energy is

$$T = \frac{\mu}{8 \pi} \iiint \left[\xi^2 + \eta^2 + \zeta^2 \right] dx dy dz.$$

Now with only one of the three coordinate planes existing, we must evidently make $\xi = 0$, $\eta = 0$; and if we suppose ξ to be the angular velocity of the wheels, we evidently obtain the right form for the kinetic energy. The potential energy depends on the squares of $+\frac{d\xi}{dy}$ and $-\frac{d\xi}{dx}$. Observe that ξ is the angle through which any wheel has rotated; then it is evident that $\frac{d\xi}{dy}$ is the rate of change of this angle along y , and is proportional to the difference of stretching of the indiarubber bands in this direction, *i. e.* to what I have compared with electric displacement in the x direction; and manifestly, if the bands obey the usual laws of elasticity, their potential energy is proportional to the square of the stretching. We see similarly that the y polarisation is $-\frac{d\xi}{dx}$. It is further evident that, with three systems of planes at right angles to one another, we must make the potential energy depend

on the squares of $\left(\frac{d\xi}{dy} - \frac{d\eta}{dz}\right)$, &c., *i.e.* the strain must be proportional to these quantities. Now the simple mechanism of elastic bands will not do this by itself, but it is quite possible to arrange mechanism by which it shall be effected; for I have been able to invent one working by means of a fluid pumped through a network of pipes, by the rotation of wheels so arranged that an accumulation of fluid in any place tends to stop the rotation. It is easy, then, to arrange that such a series of rotations as $\frac{d\xi}{dy} - \frac{d\eta}{dz} = 0$ shall produce no accumulation. Having shown, then, that the energy of this medium can be expressed in the same form as that of the ether, it follows at once that all the results deduced from this form of the energy can be reproduced on a model.

I have explained how it illustrates ordinary electric phenomena, and now I wish to show how the same medium that can illustrate these phenomena can also transmit vibrations analogous to light. If any series of the wheels be suddenly rotated, inertia will prevent those in their neighbourhood from being immediately rotated. After a little while, however, the motion will be transmitted to the neighbouring wheels, which will transmit it to their neighbours, and so on, a wave of motion being transmitted through the medium. If we consider the nature of the motion constituting the wave, it will be seen to be directed in the plane of the wave, *i.e.* the wave will be a wave of transverse vibration. The axes of rotation of the wheels are evidently at right angles to the direction of propagation of the wave, and what I have described as the direction of polarisation of the bands, is also at right angles both to the axes of rotation and to the direction of wave propagation. This is evident when we consider that the difference of rotation of neighbouring wheels is what causes the tightening of one side of a belt and the loosening of the other; and the direction of polarisation of the bands is the line joining the centres of the tight and loose sides of these polarised bands, and this line is evidently at right angles to the line joining the centres of the two wheels whose difference of rotation causes the polarisation while this latter line is evidently the direction of wave propagation. Now, this is exactly analogous to what Maxwell describes as the nature of the propagation of light in the ether. The axes of rotation represent the direction of magnetic

displacement, while the direction of polarisation is the direction of electric displacement. The direction of magnetic displacement is the direction of the plane of polarisation of the ray.

From the fact that we can represent a medium in three dimensions, such that its equations of motion are the same as those Maxwell has shown must exist in the ether, it is at once evident that it would be possible to reproduce all the phenomena of the reflection and refraction of light and of polarisation of light, and that not merely in ordinary but in crystalline media, so that it would be even possible to reproduce external and internal conical refraction and the other peculiarities of the wave surface. Two related cases may well be noticed—they are those of rotatory polarisation by crystalline and magnetised media respectively. The first would obviously be obtained by giving a twist to the planes containing the wheels, a plane polarised ray would then have its plane of polarisation twisted during its passage through the medium in the same way as the plane of polarisation of a ray of light is twisted in passing along the axis of a crystal of quartz. The phenomena of magnetised media cannot be so easily reproduced. It would evidently require that something should be rotating in the field besides the wheels, and that it and the wheels should be so connected that a rotation of the wheels should tend to change the axis of rotation of this rotating something, which, reacting on the wheels, would change their direction of rotation. Mechanism that did this would reproduce the phenomena of the rotatory polarisation of magnetised media. It is worth while remarking how it is necessary, in order to represent this phenomenon, to take into account a change produced by the wave in something besides the wheels, &c., which then reacts on the wave propagation, so that the action is altogether secondary when compared with a peculiarity of the bands or wheels themselves existing in any region independently of the wave passing through it. This latter state is analogous to the state of the ether inside a body produced by the presence of the matter that causes its refractive index and specific inductive capacity to differ from unity. The dispersion of waves of different rates of vibration is, on the other hand, a secondary action, as is illustrated by several theories of dispersion where the action of the matter in the wave propagation is due to a reaction of the matter during the wave propagation, and not a

permanent alteration by the matter of the nature of the medium of propagation

I need hardly say that I do not intend it to be supposed that the ether is actually made up of wheels and india-rubber bands, nor even of paddle-wheels, with connecting canals. I think, however, that we may learn several things as to the conditions that the elements of the ether should fulfil if they are to represent Maxwell's equations by motions in ways analogous to those of my model. This supposes that quantities, such as the magnetic displacement that obey the laws of rotation, are really of the nature of rotations. If this be so, it is evident that the elements of the medium must be capable of rotating any number of times without any distortional stress being produced, so long as the neighbouring parts all rotate equally, while distortional stress must be produced and be proportional to the difference of rotation of the neighbouring parts of the medium. It seems from this almost necessary that the ether must have some structure, and although Maxwell has objected to its having anything like a molecular structure on account of this supposition requiring it to possess specific heat, yet I venture to think that it does possess the specific heat it should possess upon the supposition of some sort of structure. Part of the energy in a volume occupied by any substance is in the form of vibrations of the ether within that volume, and the amount of this part of the energy will depend on the temperature of the body. Similarly the heat required to warm up a mass of silver enclosed in a non-conducting envelope (so that none of the energy was spent in producing vibrations in the surrounding ether) would depend on whether the silver were all in a small lump, or were in the form of a thin closed vessel, including a large volume of ether, for this included ether would require some of the energy in order to give it energy of vibration. If the law connecting the temperature of matter with the energy of vibration of the ether in contact with it were known, it would be possible to calculate in this sense the specific heat of ether. As all materials are of the same temperature when in contact with ether in the same state of vibration, this specific heat of the ether would be independent of the material of which the envelope was constructed. As the energy of the ether is all in the form of its own vibrations, and is not propagated by conduction, but by wave propagation, it is not in exactly the same

form as the heat energy in material bodies; but I see no reason for assuming that, because the ether has a structure, it must be capable of being a vehicle for heat energy of exactly the same form as that in material bodies; in fact, unless there were another ether bearing to the known ether the same relation as the known ether bears to matter, it would be impossible that the energy of the known ether should be in exactly the same form as the heat energy in matter. If the medium have a structure we can explain electric polarisation much more satisfactorily as a change of structure than as a displacement. Maxwell defines polarisation (*Elect. and Mag.*, vol. i. s. 60) generally thus:—"An elementary portion of a body may be said to be polarised when it acquires equal and opposite properties on two opposite sides." He, however, immediately afterwards calls it electric displacement, and there is danger from this of its being supposed to be merely a displacement of the medium in the direction of the electric displacement. It may be this, but I think it is very desirable that the more general notion of polarisation as a change of structure of the elements and not as a displacement of the elements should be emphasised, and it is in the latter form that polarisation is exhibited in the model. Another point to which attention is called by the model is the difference between the mechanical and the electrical stress in the medium. The model does not represent the mechanical stress at all. This latter depends necessarily on matter, for mechanical stress is a material phenomenon, and its connexion with the electric polarisation depends on the connexion between matter and ether. This is true of the mechanical forces, due to both electrical and magnetic polarisation. That the mechanical stress is not connected with the electric displacement in the same way as material stresses are connected with their material strains in solids is obvious from its being proportional to the square of the displacement, and so being independent of its direction. All theories of the ether that suppose it to be simply a jelly with matter spread through it, like grapes in a jelly, hardly seem to attribute sufficient importance to the difficulty of explaining upon any such simple hypothesis such phenomena as electricity and magnetism; and although the equations of motion of the jelly may fairly well represent the equations of motion of the ether, as regards its propagation of light, yet the properties of a jelly

prevent our supposing continuous rotation of its elements, which seems almost necessary in order that the same quantities which represent small motions in the light propagation may represent known phenomena in electricity and magnetism.

Although Professor Stokes seems to think that there is no contradiction in supposing the ether to be a jelly, and at the same time sufficiently little rigid to permit the free motion of matter through it, nevertheless, there is no doubt that this is a serious stumbling-block in the way of a general acceptance of the hypothesis that the ether is, in all respects, like a thin jelly, and I hardly think the difficulty diminished when its strains, as a rigid body, are required to be capable of producing permanent electrical forces. There are, of course, many ways in which matter may move through the ether besides by displacing it; as, for instance, in the way in which a volume of liquid water might pass through ice, namely, by dissolving in front, and by freezing as fast behind, and such hypotheses do not require any limit to be assigned to the rigidity of the ether. In all these cases it is, of course, evident, that when it is once shown that the energy of the medium depends on quantities which obey the laws of Maxwell's electric and magnetic induction and displacements, it follows that the forces on the places that represent the electrified and magnetised bodies must be the known electrical and magnetic attractions and repulsions; and one great difficulty in framing hypotheses as to the connection of the ether and matter is in explaining how the matter moves through the ether.

A very beautiful theory of matter has been founded by Sir William Thomson upon Helmholtz's theory of vortex motion in a perfect liquid, and there seems no doubt that the simplest theory as to the constitution of the ether is that it is a perfect liquid. It seems unlikely, from Professor J. J. Thomson's investigations of the properties of vortex atoms, that the simple hypothesis that an atom is a mere vortex ring in a liquid otherwise at rest is a sufficient hypothesis, and it seems almost impossible to explain electric and magnetic phenomena without some further hypothesis. The hypothesis that the ether is like a thin jelly in no way *explains* this property, as it is the possession of properties analogous to rigidity that requires explanation. Now, it seems certain that the only way in which a perfect liquid can become everywhere endowed

with properties analogous to rigidity is by being everywhere in motion. The most general supposition of this kind would be, that it was what Sir William Thomson has called a vortex-sponge, *i. e.* everywhere endowed with vortex motion, but with this motion so mixed up as to have within any sensible volume an equal amount of vortex motion in all directions. There are many ways in which this supposition seems to be in accordance with what we know of the properties of the ether. One would expect that electrostatic forces would be due to the irrotational parts of the fluid, while the electro-magnetic forces would be due to the rotational parts. There are a great many ways in which such a vortex sponge could be polarised. If it consisted of vortex filaments they might have either a solenoidal or lamellar polarisation; and if it consisted of vortex rings they might also have their motions polarised so as to move parallel to lines or planes which would correspond to solenoidal or lamellar polarisations. Besides this, the axes of the vortex filaments or rings themselves might be bent, or their sections distorted, introducing thus two new sources of forces. It is thus visible that the proposed supposition introduces modes of producing force between different parts of the medium in a sufficient number of ways to explain not only electric and magnetic forces, but cohesion and chemical forces. I have not made any supposition as to the nature of matter. The supposition that the ether is a vortex sponge in a perfect liquid, does not diminish the number of possible hypotheses as to the constitution of matter: on the contrary, it very much increases the possible modes of action of matter. I know very little as to the mechanics of a vortex sponge, but some points mentioned by Sir William Thomson, in a Paper read before the British Association at Swansea (*Brit. Assoc. Rep.*, Swansea, p. 474), seem in favour of the hypothesis. In the first place, the energy of any polarised state of vortex motion is greater than that of an unpolarised state, so that if the motion of matter reduce the polarisation, there will be forces tending to produce that motion. Now, in the case of two infinite planes separated by a region of polarised vortex motion of any kind, it seems evident that, as the forces due to a small vortex vary as a high power of the distance from it, the forces due to the polarisation between the planes will depend on this polarisation, and not on the distance apart of the planes. This is the characteristic of forces varying inversely

as the square of the distance from points spread over a plane. Sir William Thomson has also pointed out a case in which a polarised state of the vortex motion will be in equilibrium as long as it cannot produce motion of the boundary of the containing vessel, but in which if it can expend its energy in causing motion of the boundary, its energy will be so expended. From this it seems likely that there are modes of polarisation of a vortex sponge which will be in equilibrium as far as the sponge is concerned, and whose energy can only be spent on producing motion of the boundaries. This is exactly the condition required in order to explain the equilibrium of the strained ether, which itself in equilibrium tends to move objects within it. If the vortex sponge be otherwise disturbed, it is obvious that the polarised state will become distributed through the sponge, and this should be analogous to the propagation of light. It is evident that inasmuch as we could neither create nor destroy vorticity, all we could do would be to polarise the motion, and that all such polarisation would have this character of electric phenomena that we could not produce one kind of electrification without producing somewhere an equal and opposite electrification.

I have not been able to work the theory out completely, but have not come across any fatal objection to it. There are a great many suppositions that can be made as to the nature of the polarisation that represents electrostatic phenomena; and it may be of use, to anyone working at an hypothesis as to the nature of this polarisation, to recollect that it is allowable to suppose a flow continuously in one direction between electrified bodies held apart by solids, for the electric forces are then balanced by stresses in the solid supports, and these stresses may be due to the flow back of whatever is supposed to be flowing out between the electrified bodies. I do not expect that any flow continuously in one direction does take place; but there is danger of such a hypothesis being summarily dismissed, because of its being supposed to lead to an accumulation in the body towards which the flow takes place.

In conclusion, I desire to reiterate that it seems that the only way in which to impart to a perfect liquid properties at all analogous to those possessed by the ether, is by supposing it full of motion.

LII.—A CONTRIBUTION TO THE NATURAL HISTORY OF
THE HAIRS OF THE ANDRŒCIUM. BY GREEN-
WOOD PIM, M.A., F.L.S. (Plates XIX. AND XX.).

[Read, February 16, 1885.]

It is not a little remarkable that in the minute scrutiny to which the organs of Phanerogamic plants have been subjected of late years by botanists both at home and abroad, that the hairs which are to be met with on the Andrœcium and Gynœcium should have been, at least so far as I have been able to ascertain, almost entirely neglected. This seems the more strange since those on leaves, stems, &c., have had their due meed of attention, while staminal hairs present much more remarkable variations both in structure and distribution. It cannot, I think, be doubted, that these organs play a most important part in the mechanism of fertilization, so that here we have a fresh point of departure in that interesting branch of botanical science; for even in Hermann Müller's well-known works these hairs are but most casually alluded to, and their minuter structure little, if at all, noticed.

Dr. G. A. Weiss, of Prague, in his *Allgemeine Botanik*, published in 1878, devotes a considerable space to the subject of trichomes in general, but with the exception of those of *Tradescantia*, no allusion is made to those occurring on the stamens, and only one or two to those of the gynœcium or pistil. Numerous memoirs have appeared from time to time in the *Annales des Sciences Naturelles*, *Annals of Nat. Hist.*, *Botanische Zeitung*, and elsewhere, in none of which can I find any mention of Andrœcial hairs, while almost all other portions of the plant have had their trichome structures recorded. Dr. Weiss's special Paper on the subject in Karsten's *Abhandlungen* I could not obtain, as it does not appear to be in the Library of either the Linnean or Royal Societies.

My attention was first drawn to the subject by observing the dense beard on the stamens of *Anagallis tenella*, which Sowerby figures as beaded hairs similar to the well-known ones in *Tradescantia*. However, the links in the chain are very dissimilar in

A. tenella from those of *Tradescantia*. Each link resembles a dumb-bell, with prominences at each extremity like the articulations of a bone; in fact the hair is strikingly similar to a chain of metacarpal or metatarsal bones. Moreover, each link has a series of delicate spiral striæ, giving it a twisted appearance. The terminal cell is divided into a number of rounded lobes, recalling somewhat an ear of Indian corn. I next examined other species of *Anagallis*, all of which afforded stamen hairs, but none approaching in beauty or complexity to those of *A. tenella*.

It would obviously be out of the question to examine every flower to be met with, wild and in cultivation, as to the presence or absence of androecial hairs. I may, however, state that I have examined a good many, and so far the occurrence of these hairs is so irregular as to baffle anything like generalization. Thus *Thunbergia alata* has most curious hairs of two distinct forms, while the nearly allied *T. fragans* is destitute of them. *Justicia speciosa* has hairy stamens; in *J. flavicoma* they are glabrous. Hairs may occur either scattered over the surface of the filament, or be confined to the anther and the base of the filament, near its point of insertion: if the anther is hairy, there is usually a little tuft also at the base of the filament, but the latter is met with without the former in *Antirrhinum majus*.

When hairs are met with in several species of a genus, or of allied genera, there is commonly observable a strong likeness running through them, they being, as it were, variations of the same type. For example, all the *Convolvulaceæ* which have come under my observation have hairs consisting of great numbers of cells, forming a regular tissue, but terminated in every case by a very large cell, which varies both in size and shape with the particular species.

In very many instances, but not in all, the surface of the hair is somewhat roughened, either by being branched, striated, warted, or in some other way destined to hold and retain any pollen grains that may fall from the anthers, and so preserve them from the secretions of the plant itself, or other moisture which would tend to prematurely excite its development, at the same time not preventing insects from carrying it away.

I am not in a position as yet to enter into the physiological portion of the question, but I wish merely to draw attention to the

morphological details in the various species I have had the opportunity of examining. As will be seen from the annexed detailed descriptions, every form, from the simplest to the most complex, are met with, and they are often correlated with more or less irregularity in the surface of the pollen grains. In the following pages the word *multicellular* is taken as meaning composed of many rows of cells, forming a mass of parenchyma; and *pluricellular* as designating a row of cells such as would be produced by transverse septa, formed in one long, more or less cylindrical, cell.

I hope, ere long, to have the honour of submitting to the Society some further details on the subject, as well as possibly on gynœcial hairs.

As to their morphology, we may group the various forms thus:—

- (a) Simple unicellular hairs, with smooth surface, more or less subulate. *Malva*; *Campanula*.
- (β) Unicellular subulate; surface rugose, with papillæ. *Cuphea*; *Nerium*; *Eutoca*.
- (γ) Unicellular, but flattened, or spathulate, rugose or striate. *Verbascum*; *Celsia*; *Antirrhinum*.
- (δ) Pluricellular; simple; smooth. *Salvia* (some forms); *Adhatoda*.
- (ε) Pluricellular; simple, rugose, or striate, not glandular. *Anagallis*; *Goldfussia*; *Thunbergia*.
- (ζ) Pluricellular; branched, not glandular. *Browallia*; *Salvia* (some forms).
- (η) Pluricellular, with glandular tip. *Oxalis*; *Æschynanthus*; *Gesnera*.
- (θ) Multicellular. *Convolvulus*; *Ipomæa*; *Lasiandra*.

Stamen hairs have been observed by the writer in the following nineteen natural orders, viz.:—*Malvaceæ*, *Oxalidaceæ*, *Melastomaceæ*, *Rutaceæ*, *Hydrophyllaceæ*, *Lythraceæ*, *Campanulaceæ*, *Lobeliaceæ*, *Convolvulaceæ*, *Rubiaceæ*, *Apocynaceæ*, *Labiataæ*, *Acanthaceæ*, *Scrophulariaceæ*, *Gesneraceæ*, *Ericaceæ*, *Primulaceæ*, *Commelynaceæ*, *Liliaceæ*;¹ but it is probable that further investigation will reveal their presence in very many others.

¹ Since the foregoing was written, hairs have been observed on the stamens of *Crocus*, thus adding to the above list the *Iridaceæ*.

MALVACEÆ.

Malva moschata.—Hairs scattered over the filament; tapering; slender; cell wall thick; suddenly contracted at the base, where they arise from a delicate papilla; diameter about $\cdot 0015$ in. (pl. XIX., fig. 1).

OXALIDACEÆ.

Oxalis lasiandra.—Hairs of two kinds (*a*) unicellular, straight or curved; tapering to a blunt point; cell wall thickened; surface thickly beset with protuberances; about $\cdot 0008$ in. in diameter; (*b*) pluricellular, clavate, glandular, thick-walled, especially the terminal cell, which is filled with dark contents; $\cdot 0010$ in. in diameter (pl. XIX., fig. 6).

HYDROPHYLLACEÆ.

Eutoca viscida.—Hairs distributed over filament, of two forms, viz.:—(*a*) unicellular; very long and slender; tapering gradually; very thin wall; slightly dotted with minute flattened papillæ, which are ovate, with long axis parallel to that of hair; diameter $\cdot 0006$ – $\cdot 0010$ in. (pl. XX., fig. 1 *a*); (*b*) shorter; glandular; clavate; pluricellular; thicker wall. Two distal cells; sometimes divided by vertical septa. Diameter $\cdot 0070$ (pl. XX., fig. 1 *b*).

LYTHRACEÆ.

Cuphea zimapani.—Hairs distributed over filament; long; filiform; unicellular; intertwining; very slender; cell wall thin; densely covered with minute papillæ; obtuse; scarcely tapering; forming a dense wool. Diameter $\cdot 0006$ in. (pl. XIX., fig. 2).

MELASTOMACEÆ.

Lasiandra macrantha.—Hairs distributed over filament; multicellular; bulbous at base; extremity clavate; glandular; formed of cells closely packed round a central space; cell contents purple. Diameter, shaft, $\cdot 0015$; head, $\cdot 003$ (pl. XX., fig. 4 *a*, *b*).

RUTACEÆ.

Eriostemons nereifolius.—Hairs on expanded base of filament; of two kinds—(*a*) on upper portion rather long and slender; wall thin; somewhat tuberculate; tubercles becoming fewer towards

base of hair. Diameter $\cdot 0008$ in. (pl. xix., fig. 3); (b) on basal portion shorter, with bulbous base; tapering; very thick wall; scarcely tuberculate; $\cdot 0018$ in. diameter (pl. xix., fig. 4).

CAMPANULACEÆ.

Campanula fragilis.—Hairs expanded on basal part of filament, rather long and slender (as compared with other species of *Campanula*, in which hairs very similar, though varying greatly in size, are found); somewhat flexuous; wall strongly marked; generally obtuse, but sometimes acute; very numerous. Diameter $\cdot 001$, by $\cdot 025$ long.

C. portenschlageana.—Hairs on base of filament obtuse; short and thicker than in *C. fragilis*; resembling tentacles of actinia; wall thin. Diameter $\cdot 0015$ – $\cdot 0020$.

C. medium.—Hairs on edge of filament very short and thick; somewhat papillate at top; wall well marked; closely packed. Diameter $\cdot 003$ – $\cdot 005$ in. by $\cdot 01$ – $\cdot 03$ long (pl. xix., fig. 5).

CONVOLVULACEÆ.

In all the members of this order which I have examined the hairs are very characteristic, distributed generally over the filament; multicellular, with a large terminal cell, which, as well as the size of the hair, varies in different species; the terminal cell is least marked in *Calystegia sepium* and *C. sylvatica*, reaching its highest development in *Ipomœa purpurea* and *Convolvulus mauritanicus*. In *Convolvulus tricolor*, a non-scandent form, the stamens are glabrous.

Convolvulus mauritanicus.—Hairs comparatively slender; rather short; terminating in a large piliform, obtusely triangular cell, which is filled with granular protoplasm. Diameter $\cdot 002$ – $\cdot 003$. (pl. xx., fig. 2).

Ipomœa learii.—Hairs very long and slender, composed of a great number of exceedingly delicate cells; terminal one oblong, obtuse; equal in transverse diameter to shaft of hair, and about twice as long. Diameter $\cdot 002$ in. (pl. xx., fig. 5). Pollen spherical; spiny.

I. purpurea.—Very similar to *I. learii*, but larger in all its parts; terminal cell square. Diameter $\cdot 002$ – $\cdot 003$ in. (pl. xx., fig. 3).

I. (?) species.—Also similar to *I. purpurea*; terminal cell longer, more slender, and pointed. Diameter $\cdot 006$ by $\cdot 0015$ (pl. xx., fig. 6).

I. coccinea.—Hairs very short, often mere protuberances; terminal cell scarcely exceeding the others (which are much larger than in other species of *Ipomæa*), but is flattened and oblique, resembling those of *Calystegia*. Diameter $\cdot 006$; terminal cell $\cdot 0006$ long by $\cdot 003$ wide (pl. xx., fig. 7).

Calystegia sepium.—Hairs very short, composed as in the last of a few large cells; terminal cell but little differentiated. Diameter $\cdot 003$ (pl. xx., fig. 8).

C. sylvatica.—Similar to *C. sepium*; more slender; cells longer; terminal cell scarcely distinguishable from others. Diameter $\cdot 0025$ in.

LOBELIACEÆ.

Lobelia cardinalis.—Hairs distributed on filament; dense; variable, short and thick, or long, and somewhat slender; unicellular; very rugose, with minute warts. Diameter $\cdot 0010$ (pl. xix., fig. 7).

L. erinus.—Hairs very scanty on filament; rather short; wall extremely delicate; smooth, with a few comparatively long granules. Diameter $\cdot 0008$ (pl. xix., fig. 8). Pollen slightly uneven in outline.

SCROPHULARIACEÆ.

The hairs in this order are usually flattened, wider at the apex than at the base, hence often more or less spathulate (except *Browallia*).

Browallia elata.—Distributed over filament; somewhat dense; pluricellular; often branching, chiefly unilaterally, like deer's antlers; somewhat thick; wall delicate. Diameter $\cdot 0013$ – $\cdot 0015$ in. (pl. xix., fig. 11). Pollen polyhedral.

Verbascum nigrum.—Filament densely bearded with purplish hairs, which are large; spathulate; rugose, with minute ovate warts placed obliquely across the hair; variable in size. Diameter across top, $\cdot 0050$; of shaft, $\cdot 0010$ (pl. xix., fig. 13). The other species of *Verbascum* present similar hairs, varying only in colour and size.

Celsia arcturus.—Hairs very similar to *Verbascum*, scarcely distinguishable (pl. xix., fig. 12, *a*, *b*).

Antirrhinum majus.—Hairs at extreme base of filament only, resembling those of *Verbascum* and *Celsia*, but much smaller, and minutely rugose (pl. xix., fig. 21). Diameter $\cdot 0010$.

GESNERACEÆ.

Gesnera insignis.—Hairs distributed over filament; pluricellular; rather large; thin walled; knobbed at the extremity; glandular; terminal cell subdivided into several by perpendicular septa, and filled with dark coarsely-granular protoplasm (pl. xx., fig. 11). Diameter $\cdot 0010$ in.

Eucodonia sp. (garden hybrid).—Hairs pluricellular, knobbed, but not glandular; more slender than in the last; wall delicate. Diameter $\cdot 0008$ in. (pl. xx., fig. 10).

Aeschynanthus splendens.—Hairs scattered over filament, resembling those of *Gesnera insignis*, but smaller; pluricellular; glandular terminal cell, divided by perpendicular septa, as in *G. insignis*, septa fewer in number. Diameter $\cdot 0007-8$ in. (pl. xx., fig. 9).

APOCYNACEÆ.

Nerium oleander.—Hairs clothing filament with a soft woolly coating; very slender; unicellular; wall well marked; rugose, with minute oblique warts. Diameter $\cdot 0008$ in. (pl. xix., fig. 9).

RUBIACEÆ.

Toxicophlœa spectabilis.—Hairs of two kinds—(a) on anther; unicellular; rather short; flattened; slightly rugose, with extremely minute papillæ; diameter $\cdot 0008$ in.; (b) on filament longer, but unicellular; subulate; obtuse, with one or two slight swellings of the cell wall; partly filled with large rounded granules. Diameter about $\cdot 0008$ in. Similar hairs occur on the corolla tube.

Vinca major.—Hairs on extremity of anther and at base of filament, where it is inserted into the tube of the corolla; both unicellular; surface faintly undulated. Those on the anther, with thinner walls and longitudinally striate. Diameter $\cdot 0008$. Those at base of filament with stronger walls, also striate, and with very granular protoplasm. Diameter $\cdot 0010$. Pollen smooth.

Vinca minor.—Hairs very similar, both as to form and arrangement, to those of *V. major*, but outline of anther hairs more undulated and scarcely striate. Diameter $\cdot 0008-0010$. Pollen smooth, with three or four projections. Basal hairs less undulate but more striate.

LABIATÆ.

Salvia is the only genus of the order in which I have observed androëcial hairs.

S. splendens.—Scattered over filament, pluricellular, very delicate, wall very thin, usually simple, rarely branched; tip very obtuse. Diameter $\cdot 0010$.

The closely allied *S. heeri* has very similar hairs, but more swollen at the nodes.

S. fulgens.—Hairs large, deep red, wall strongly marked, rarely branched, slightly verrucose, with minute warts. Diameter $\cdot 0015$.

S. rutilans.—Almost simple, short, thick, wall delicate, unicellular. Diameter $\cdot 0015$ (pl. XIX., fig. 14). Pollen slightly rugose, deeply sulcate.

S. leucantha.—While the whole plant, especially the calyx, is unusually downy, the stamens are nearly glabrous, the hairs which do occur differing considerably from those of the other species I have examined. Those on filament—(a) are very short and thick, either obtuse or capitate, consisting of two or three flattened cells. When capitate the head is nearly globose; (b) at base of filament very short, simple, obtuse, scarcely more than papillæ; unicellular.

PRIMULACEÆ.

Anagallis arvensis.—Stamens very woolly; hairs pluricellular, with delicate wall; lower cells oblong; upper two nearly spherical; all delicately striate, with longitudinal striæ; deep purple in colour, whether petals happen to be red, blue, or white. Diameter $\cdot 0008$ (pl. XX., fig. 12).

<i>A. parksii</i> (<i>monelli</i>) (pl. XX.,	{	Very similar to <i>A. arvensis</i> , but with terminal segments more oblong.
fig. 13).		
<i>A. phillipsii</i> (pl. XX., fig. 14).	{	

A. indica (pl. XX., fig. 16) has terminal cell more spherical, and showing traces, occasionally, of a vertical septum.

A. var. *Napoleon III.* (pl. XX., fig. 15). Segments longer; broader at ends than in the centre, thus somewhat resembling such a bone as a human femur or humerus. In all these forms the cell wall is exceedingly thin, but appears often somewhat thick on

account of the protoplasm contracting but slightly, the space between the mass of protoplasm and the wall appearing to be the wall itself. In the terminal cell becoming vertically septate (*A. indica*), and the resemblance to a bone (*A. Napoleon III.*), we trace the transition to the most differentiated form, *A. tenella*, which is very distinct in habit and flower from all the others, while in the strikingly similar (to *A. arvensis*) *Lysimachia nemorum* the stamens are quite glabrous. The pollen in the five species just described is somewhat triangular in outline.

A. tenella.—Filament woolly, with pluricellular hairs, the lower segments of which resemble dumb-bells, with knobs projecting from the ends at right angles to the long axis; they might also be likened to metacarpal bones, as before mentioned. Terminal cells much smaller, rounded, arranged in a kind of ear-like form, arising from repeated transverse and vertical septa; all with a delicate spiral striation (pl. xx., fig. 17). Diameter $\cdot 0007$ – $\cdot 0012$ (across knobbed portion). In the young bud we find hairs in all stages, from the simple pluricellular form of *A. philipsii* to the fully developed form. Pollen small, smooth, oval.

ACANTHACEÆ.

Hairs occur in many genera and species, and vary a good deal, but are generally pluricellular, often presenting two or more types on different parts of the same stamen (*Acanthus*, *Thunbergia*). In *Acanthus* the hairs are very largely developed, the anther having quite a brush-like appearance.

Acanthus spinosus.—Hairs occur both on anther and at base of filament. Those on the anther are of two forms—(a) short and stiff, forming a dense brush on the ventral suture of the anther, with the surface reticulated in a labyrinthiform manner; (b) on the dorsal portion of the anther, longer, more flexuous, stronger walls, and with only longitudinal striæ. The position of these dorsal hairs varies according to whether the anthers are those of the interior or exterior pair of stamens, the anthers of the latter being closely appressed to each other by their ventral sutures. The basal hairs resemble those dorsally situate on the anther. Their diameters are about the same, viz., $\cdot 0010$ in. (pl. xix., fig. 18). Pollen oval, slightly papillate.

Acanthus montanus.—Arrangement of hairs similar to *A. spinosus*, but sutural hairs not reticulated, and scarcely differing from dorsal, except in having a blunt tip, while the latter are somewhat knobbed. Diameter $\cdot 0010$. Pollen round, smooth (pl. XIX., fig. 19 *a* and *b*).

Thunbergia alata.—Hairs of two kinds—(*a*) clothing edge of anther, pluricellular, upper cells large, spheroidal, thick-walled; terminal, one or more septate; lower oblong, all thickly beset with prominent warts; diameter $\cdot 0010$ – $\cdot 0025$ in. (pl. XX., fig. 19); (*b*) at base of filament, thick, pluricellular; cells long, oval, terminal, flattened transversely; wall rather thin, scarcely at all scabrous; protoplasm very granular; proximal segment smallest. Pollen spherical, with enveloping spiral band (pl. XX., fig. 18).

Justicia speciosa.—Hairs on filament short and thick, or somewhat slender; pluricellular; slightly scabrous; wall rather thin; deep purple; curved. The endochrome has the remarkable property, in common with that of the petals, &c., of crystallizing into minute prisms of dark purple colour. Diameter, thick hairs, $\cdot 0015$; slender, $\cdot 0010$ (pl. XIX., fig. 17).

J. flavicoma.—Anthers glabrous.

Goldfussia anisophylla.—Hairs on filament long; flexuous; longitudinally flattened; pluricellular; simple or slightly branched; wall delicate; scabrous, with minute warts, as in *Nerium*, *Verbascum*, &c. Diameter $\cdot 0007$ (pl. XIX., fig. 16). Pollen nearly round; furrowed; slightly roughened.

Adhatoda cydoniaefolia.—Hairs on filament thickly disposed; pluricellular; somewhat swollen at septa; wall well marked; slightly striate longitudinally; point acute. Diameter $\cdot 0010$ (pl. XIX., fig. 20).

ERICACEÆ.

Arbutus unedo.—Expanded portion of filament thickly beset with rather long, extremely delicate, unicellular, simple hairs, which are very slightly scabrous with minute oval projections; about $\cdot 0004$ in. in diameter. These are the slenderest hairs I have met with (pl. XIX., fig. 21).

Arbutus procera.—Hairs undistinguishable from those of *A. unedo*.

MONOCOTYLEDONES.

COMMELYNACEÆ.

Tradescantia virginica.—Stamen thickly covered with dark blue hairs, in which, as is well known, the rotation of the cell sap can be seen. They are pluricellular, much constricted at the septa, so as to form a bead-like structure.

Tradescantia zebrina and *Commelyna cælestis* present similar hairs.

LILIACEÆ.

Yucca sp.—Hair on filament very thick; rather short and obtuse; unicellular, with longitudinal striæ; wall (proportionately) thin. Diameter $\cdot 005$ (pl. XIX., fig. 15).

Narthecium ossifragum.—Hairs on filament; pluricellular, rather slender, obtuse; wall delicate; closely striate, with spiral striæ; each cell containing a considerable number of bright orange globules of various sizes and shapes, probably oil of some kind. Diameter $\cdot 0010$ (pl. XIX., fig. 22).

DESCRIPTION OF PLATES XIX. AND XX.

PLATE XIX.

On Plate XIX., figs. 1, 4, 5, 7, 12*a*, 15, 20, are magnified about 40 diameters; figs. 2, 3, 6, 8, 9, 10, 11, 12*b*, 13, 14, 16, 17, 18, 19, 21, 22, about 175 diameters.

- | | | |
|------|-----|---|
| Fig. | 1. | <i>Malva moschata</i> . |
| „ | 2. | <i>Cuphea zimapani</i> . |
| „ | 3. | <i>Eriostemon neriifolius</i> . |
| | | Hair on upper portion of filament. |
| „ | 4. | <i>Eriostemon neriifolius</i> . |
| | | Hair from lower portion of filament. |
| „ | 5. | <i>Campanula medium</i> . |
| „ | 6. | <i>Oxalis lasiandra</i> . |
| „ | 7. | <i>Lobelia cardinalis</i> . |
| „ | 8. | <i>Lobelia erinus</i> . |
| „ | 9. | <i>Nerium oleander</i> . |
| „ | 10. | <i>Antirrhinum majus</i> . |
| | | Basal hair. |
| „ | 11. | <i>Browallia elata</i> . |
| „ | 12. | <i>Celsia arcturus</i> . |
| | | <i>a.</i> Group of hairs; <i>b.</i> Single hair highly magnified. |

DESCRIPTION OF PLATE XIX.—continued.

- Fig. 13. *Verbascum nigrum*.
 „ 14. *Salvia rutilans*.
 „ 15. *Yucca* sp.
 „ 16. *Goldfussia anisophylla*.
 „ 17. *Justicia speciosa*.
 „ 18. *Acanthus spinosus*.
 Hair on suture of anther.
 „ 19. *Acanthus montanus*.
 a. Sutural hair; *b.* Dorsal hair.
 „ 20. *Adhatoda cydoniæfolia*.
 „ 21. *Arbutus unedo*.
 „ 22. *Narthecium ossifragum*.

PLATE XX.

On Plate XX., figs. 2 and 18 are magnified about 40 diameters—all the rest
 175 diameters.

- Fig. 1. *Eutoca visida*.
 a. Ordinary hair; *b.* Glandular hair.
 „ 2. *Convolvulus mauritanicus*.
 „ 3. *Ipomæa purpurea*.
 Extremity of hair.
 „ 4. *Lasiandra macrantha*.
 a. Longitudinal section; *b.* Surface of tip.
 (Diagrammatic.)
 „ 5. *Ipomæa learii*.
 Extremity of hair.
 „ 6. *I. (?) species*.
 Extremity of hair.
 „ 7. *Ipomæa coccinea*.
 „ 8. *Calystegia sepium*.
 „ 9. *Æschynanthus splendens*.
 „ 10. *Eucodonia (?) species*.
 „ 11. *Gesnera insignis*.
 Tip of hair.
 „ 12. *Anagallis arvensis*.
 „ 13. *Anagallis monelli (parksii)*.
 „ 14. *Anagallis phillipsi*.
 „ 15. *Anagallis*, var. *Napoleon III.*
 „ 16. *Anagallis indica*.
 „ 17. *Anagallis tenella*.
 „ 18. *Thunbergia alata*.
 Basal hair.
 „ 19. *Thunbergia alata*.
 Anther hair.

LIII.—ON A SET OF MUSICAL STONES IN THE SCIENCE
AND ART MUSEUM, DUBLIN. BY BENJAMIN H.
MULLEN, B.A., DUBLIN.

[Read, January 19, 1885.]

THE stones now exhibited, by permission of the Director, Science and Art Museum, formed a set of musical stones which were on view in the Museum of the Royal Dublin Society about twenty-five years ago; many years before they were handed over, with the entire collections of the Society, to the Science and Art Department. They were found in a box in a store-room a few months ago; and, having been brought to light and arranged, they form the rude, but tuneful instrument known as the Rock Harmonicon.

But, before entering into any particulars about these, it might be interesting to say something of musical stones in general.

From a work by Fétis, entitled *L'Histoire Générale de la Musique*, we learn that different sonorous stones are found in China, the best of which, called *yu*,¹ is hard, heavy, and close-grained, and takes a polish like agate. These stones are given an uniform shape, and are arranged in a series conformable with the tonal system of the Chinese. The arrangement of this series of sounding-stones is called *king*. The stone *yu* is put into vibration by a blow from a metal hammer or wooden mallet. Their shape, as I gathered from an illustration in the above-mentioned work, is like a pistol-holster, flattened considerably. They are suspended in two rows of eight from the bars of a framework of wood, somewhat resembling a large clothes-horse in appearance. The smaller stones are hung from the upper bar, the larger from the lower.

¹ The Chinese *yu* stone is Jade. According to Goez (16th century) this stone was sold at "exceeding great rates" in China, and was regarded as most precious.

From another source¹ we hear that among the ancient Chinese musical instruments is the *pein king*, which is an assortment of sixteen stones arranged on strings in two series of eight each, one above the other, and giving out, when struck successively, the system of sounds employed by the ancient Chinese in their music. The size and shape of these stones have been very carefully determined by them, after a minute analysis of the sounds peculiar to each one. In order to render the sound graver, the thickness of the stone is diminished to the right amount, and to render it more acute something is cut off its length. Frequent endeavours have been made to decide what kind of stone was employed, since they were customarily paid as tribute-money, more than two thousand years before Christ, by certain provinces in China. Some authors have thought they recognized in them a kind of black marble; and the editor of the works of Father Amiote asserts that the musical stones constructed in France, with the black marble of Flanders, were quite as sonorous as those of China.

The ancients turned to account the acoustic properties of certain kinds of stone in a remarkable way.² Pausanias tells of a marvellous stone that was placed as a sentinel at the entrance of a treasury; and that robbers were scared away by the trumpet tones which it sent forth. Several kinds of stone have this property of resonance, and it is probable that a stone of this description was so suspended as to be struck by a projecting piece of metal when the external door of the treasury opened.

The clink-stone indicates by its very name its sonorous qualities. The red granite of the Thebaid in Egypt possesses similar properties. And so musical are the granite rocks on the Orinoco, that the natives attribute the sounds to witchcraft. In Brazil travellers have seen large blocks of basalt which emitted very clear sounds when struck; and the Chinese employ this stone in the manufacture of musical instruments.

Many years ago a discovery was made at Kendal, in Westmoreland, of some musical stones which, when struck with a piece of iron, or another stone, gave out sounds of very different pitch, and with eight of which it would be possible to attain a very dis-

¹ The Practical Dictionary of Mechanics, by Edward H. Knight, C.E.

² The World of Wonders.

tinct octave. And a correspondent of *Nature* writes that, in roaming over the hills and rocks near Kendal, which are composed chiefly of limestone, he had often found what are called musical stones. They are generally thin, flat, weather-beaten stones, of different sizes and peculiar shapes, which, when struck, produce a musical tone instead of the dull, heavy, leaden sound of an ordinary stone. The sounds of these stones are very much alike; but sets of eight have been collected which produce a distinct octave. The French scientific weekly, *La Nature* copied the communication from its English namesake, and brought forward an additional instance of the same phenomenon. It told of a performer who played airs on rough flints suspended by silk threads, striking them with an iron rod. And, to come nearer home, Ireland is not without her singing stones. I hear there is a bridge, between Ballina and Belmullet, whose coping stones are particularly sonorous.

With regard to the set at present before us, there is, unfortunately, very little information to be had. They were presented to the Royal Dublin Society by Miss Hunt, of 10, Upper Merrion-street, on 1st December, 1857—more than twenty-seven years ago—under the title of “A Set of Musical Stones from Cumberland.”

A set of probably similar stones, consisting of sixty pieces, varying in length from six inches to four feet, and having a compass of five octaves, was collected about thirteen years ago in Cumberland by an artizan named Till, of Keswick.¹ This, like the set in the Science and Art Museum, is not a mere musical curiosity, but an effective instrument which draws a hall full of people whenever its inventor appears in public. He would deserve such support, for the time occupied in completing the set was eleven years. I believe its range has since been extended by some fifteen or twenty stones. Three perform on it at the same time; and the effect is as pleasing as it is novel. At the late Amsterdam Exhibition, and elsewhere since, a Frenchman exhibited a set of twenty-five large, clear-sounding

¹ Mr. Peter Crosthwaite, founder of the Crosthwaite Museum, Keswick, discovered the first musical stones, on June 11, 1785, on the sand-beds of the river Greta, near Keswick. This set consists of sixteen in number, upon which any tune in the natural key can be played. They are composed of hornblende slate and gneiss, two of the lower rocks of the Skiddaw strata.—*Notes and Queries*, No. 267, p. 112.

flints; and, as with that in the Museum, there was no relation between the weight, size, or shape of the stones and the notes produced. He asked for it the modest sum of sixty thousand francs, nearly £100 for each stone. But the collection was the result of thirty years' labour.

The stones in the Museum are *Limestone*.

Some imagine that they are virgin stones, unhewn, unshaped but by nature; while others maintain that they have been tuned by chipping pieces off the edges. Both these ideas may be correct; they are not really incompatible. The stones are unhewn, and have no particular shape except thinness. But what could be more natural than for the collector, when he had found a stone nearly in tune, to try the effect of chipping. This "tunes" it, but does not give it resonance, for that belonged to the original stone in its virgin condition.

I tried an experiment on one of them, which had a duplicate in the scale of B flat, and noted the result. The stone (which seemed to have been broken before), weighed 273 grammes, and produced the note F, when struck. A piece was carefully removed by a stonecutter, and I then found it to weigh 247 grammes. Thus it lost 26 grammes, or $\frac{2}{21}$ of its entire weight; and the effect of this was to raise the pitch a full fourth—to B flat. This note is almost beyond the perception of the human ear; but the experiment places beyond a shadow of a doubt the fact that the stones can be tuned. It would also appear, on comparing the cause and effect, that the tuning is a very delicate operation. When pieces are removed from the edges the pitch is raised, and when taken from the flat sides it is lowered; and if, perchance, too much is removed in one way, it must be rectified in the other.

The evident difficulty of tuning the stones will account for the fact that only some four or five of this set are actually correct; the others are very nearly so. In general aspect the stones become smaller and lighter as the scale ascends; but there seems to be no relation between the weight and tone in any particular case. Take, as perhaps the most prominent instance of this, counting from the lowest note, Nos. 5 and 6. No. 5 weighs 792 grammes, while No. 6 weighs 1830 grammes; and though the latter is nearly two and a-half times as heavy as the former, it produces a note a semi-tone higher. Then, again, Nos. 7 and 8. The former, G, weighs

1485 grammes; while the latter, F, weighs only 437 grammes. In this instance the lower note is about three and a-quarter times the weight of the higher. Many other incongruities could be shown, did space permit.

The ringing quality of the stone depends on its points of suspension. Of course there are lines of vibration in the stone, and in these lines are nodal points, or points of no vibration. It is at these points the stone must be supported, otherwise the support will greatly interfere with the ring of the note. A stand constructed to meet this would be a most complicated one. Besides that, it must be so long that the walking exercise of scale playing would be so very exhausting as to entirely overcome the pleasure derivable from the otherwise entrancing performance.

Some of these stones give out a double sound; the lowest, for example, when struck, sounds A flat and E natural—a minor sixth. But I will merely draw your attention to two. First, No. 7 produces G and B flat—a minor third; the whitened part of the stone gives G, and the points which give the most distinct B flat are reddened. The other is No. 10. This is C, producing also D—a full tone. The C-producing part is white, and the D-, where clearest, blue. You will observe that these stones have four points (marked with black dots on the white ground) diametrically opposite each other, which give the *true* note of the stone, while between each of these is a spot where the *false* note is given very clearly; and in the centre, where the lines of vibration cross, it is impossible to get either note true.

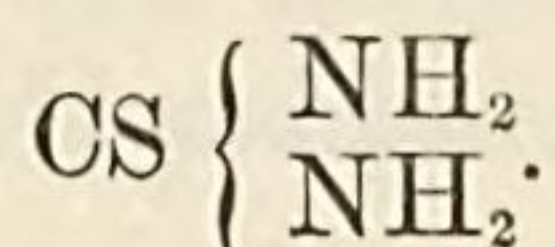
In conclusion, this Rock Harmonicon is an effective musical instrument, made of limestone in its natural condition; contains some stones which produce double sounds—some in sixths, some in thirds, some in seconds. That such sets are not common may be gathered from the fact that so little information is to be had concerning them.

LIV.—NOTE ON SELENO-CARBAMIDE. BY PROFESSOR
EMERSON REYNOLDS, M.D., F.R.S.

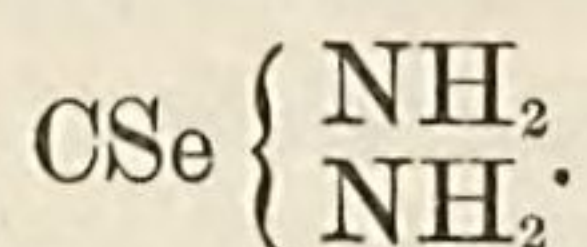
[Read, January 19, 1885.]

THE subject of the present "Note" is the selenium analogue of a body whose isolation I had the honour to announce to the Royal Dublin Society in 1869, namely, thio-carbamide. The following formulæ indicate the relations of thio- and seleno-carbamides:—

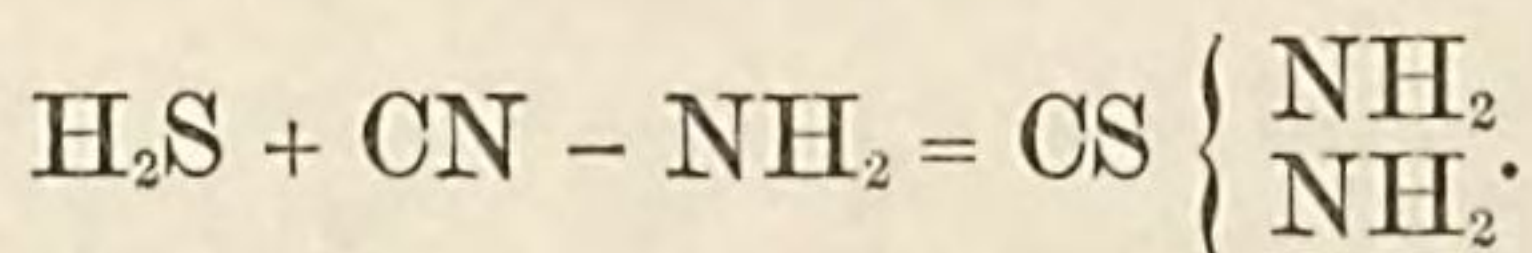
THIO-CARBAMIDE.



SELENO-CARBAMIDE.



The method by which I succeeded in producing the sulphur compound was the intra-molecular rearrangement by ammonium throughout. But the same body can be obtained by the action of hydrogen sulphide on cyanamide, thus:—



The close analogy existing between sulphur and selenium led us to expect that seleno-carbamide would be obtained by methods similar to those which have proved successful in the case of the sulphur compound. I was aware that several chemists unsuccessfully attempted to produce the body by the molecular rearrangement of ammonium seleno-cyanate; and, having recently prepared considerable quantities of cyanamide, I decided to try whether the second method would prove more successful, namely, the action of hydrogen selenide on cyanamide. The experiment, which proved successful, was conducted as follows:—

Four grams of cyanamide were dissolved in 50 ccs. of anhydrous ether, and a slow current of hydrogen-selenide was passed through the solution under a pressure of about 60 mms. of mercury. The gas was slowly absorbed, and at first some selenium separated

from the liquid ; but on continuing the treatment, beautiful colourless crystals formed on the sides of the vessel. The crystals were drained from the ethereal liquid, and when exposed to the air were found to be easily reddened by the action of light ; they were dissolved in a small quantity of hot water, the solution filtered and then cooled, when beautiful silky crystals separated which very closely resembled thiocarbamide in appearance, and mode of crystallization. The purified compound proved on analysis to be $\text{CSe}(\text{NH}_2)_2$.

When this point had been reached, the author learned from the January number of the "Journal of the Chemical Society of London," that M. A. Verneuil had just published an account of the same body in the *Bulletin de la Société Chimique de Paris*. I therefore did not continue the investigation, as M. Verneuil is fully entitled to priority, but now content myself with the exhibition to the Society of the specimen of seleno-carbamide produced in the Dublin University Laboratory.

LV. — ON AN ANALOGY BETWEEN ELECTRIC AND
THERMAL PHENOMENA. BY GEORGE FRANCIS
FITZGERALD, F.T.C.D.

[Read, November 17, 1884.]

THE object of the following communication is to show how little we know of the nature of what are called electric currents, by pointing out that electric quantities may be described in terms of temperature and entropy just as satisfactorily as in terms of pressures and volumes, which are the terms analogous to electric potential and quantity of electricity in consonance with the usually drawn analogy between an electric current and a current of an incompressible fluid, upon which is founded such terms as electric current and electric displacement. The thermal analogy usually drawn is between quantity of electricity and quantity of heat; but I think the analogy I am pointing out in every way preferable, for energy is of the nature of temperature by entropy, just as it is of the nature of pressure by volume or potential by quantity of electricity. The work done in bringing a quantity of entropy, ϕ , from temperature T_1 to T_2 is $W = (T_1 - T_2)\phi$; and if the transference be effected in a reversible manner the entropy taken from one source is equal to that given to the other. Indeed we can easily conceive of systems in which all transference of entropy is effected without loss, and in that case the quantity of entropy would be constant. It is to be observed that the temperature and entropy of a body are quite independent of one another, so that we can suppose either to be altered while the other remains constant. If we apply this conception to electrostatic phenomena, we must call potential the temperature of the ether and quantity of electricity its entropy. As the same relations connect these pairs of analogues with energy they will obey similar laws, and what is further required is to show how it may be supposed that bodies at different temperatures can throw the intervening medium into the sort of stress that Maxwell has shown is required to explain electrostatic forces. I premise that Maxwell has not made any attempt in his electricity and

magnetism to make the corresponding step of showing what sort of a thing an electric displacement is that it may produce these stresses, so that the line I am pointing out goes beyond Maxwell's analogy, but must be considered as only a dim sort of hypothesis, and not as a complete theory.

In the first place, it is evident that a non-conductor must be a medium that can have different temperatures at different parts without entropy being conducted from one place to another, *i. e.* without conduction of energy; and a conductor must be an engine that transfers entropy undiminished, and always produces heat or work equivalent to the degradation of entropy.

Now a distribution of molecules of a gas and their velocities is possible by which there would be stresses in the gas similar to those required by electrostatic phenomena, and yet without either currents of gas or conduction of heat taking place. The molecules of a material gas do not get themselves or their velocities distributed in this way by differences of temperature: in all material gases there is certainly conduction of heat, but it seems probably possible to invent a law of action between molecules which shall produce any required law of distribution of molecules and their velocities. A somewhat similar problem was solved by Maxwell when he calculated the law of force between molecules, in order that the temperature at all points in a column of gas subject to gravity might be the same. As the whole thing is so hypothetical, I have not thought it worth while attempting to work out the law of action between molecules that would account for the distribution of velocities required by my hypothesis.

If the number of molecules going in a direction defined by a direction angle θ be represented by ($\mu \equiv \cos \theta$)

$$m = m_0 + m_2 (\mu^2 - \frac{1}{3}) ;$$

and if the velocity of the corresponding molecules be

$$v = v_0 + v_2 (\mu^2 - \frac{1}{3}),$$

then there will be neither currents of gas nor to the second order of small quantities any conduction of heat, but the pressure will be different in different directions, and will be parallel to the direction from which θ is measured,

$$p_z = P + p,$$

and in every direction at right angles to this

$$p_r = P - p,$$

where

$$P = \frac{4}{3}\pi (v_0 - \frac{1}{3}v_2) \{m_0v_0 + \frac{1}{3}m_0v_2 - \frac{2}{9}m_2v_2 + \frac{1}{15}(m_2v_0 + 2m_0v_2 - m_2v_2)\},$$

and

$$p = \frac{1}{15}\pi (v_0 - \frac{1}{3}v_2) \{m_2v_0 + 2m_0v_2 - m_2v_2\}.$$

If in this m_2 and v_2 be negative quantities, p will be negative, and the state of stress will be a pressure less than the average along the line from which θ is measured, and an equal excess above the average pressure in every direction at right angles to this; and this is the state of stress that Maxwell has shown will explain electrostatic forces.

If we take the particular case of two parallel planes and suppose P and p constant all the way across, as they evidently must be, we have, supposing $m_2 = 0$, that $m_0v_0^2$ and $m_0v_0v_2$ must be constant as we go across, so that v_0 and v_2 must vary inversely as the square root of m_0 ; and if we suppose temperature defined by the square of the velocity, *i. e.* by v_0^2 we have that it must be of the form $T_0 + T_1r$, where T_0 and T_1 are constants and r the distance from one of the planes.

In this method of describing electrostatic phenomena, what Maxwell calls the electric displacement would be proportional to the square root of p ; and what he describes as the polarisation of the medium I would describe in the same words, and explain as a distribution of the molecules and their velocities in which these were not uniformly distributed in every direction.

I have not propounded any hypothesis as to the nature of conduction, but it would evidently correspond to a transference of entropy by means of heat engines which would produce heat corresponding to the resistance of the conductor, and also produce magnetic phenomena in the neighbouring dielectric. I have not propounded any hypothesis as to the nature of magnetic displacements, but it seems probable that they might be illustrated by introducing molecular rotation.

I am bringing forward this communication not at all so much for the sake of the hypothesis it contains as for the sake of calling

attention to the purely analogical nature of the description of electric currents as currents, and electric displacements as displacements. The analogy between electric currents and currents of an incompressible fluid is so complete and so easily drawn, that there is serious risk of our being as much hampered in future advances by our imagining this analogy to be a likeness as we have been in the past by the theories of action at a distance, which still control the text-books and the ordinary methods of speaking of electrical phenomena to such an extent that most people find it almost impossible to think of electric and magnetic phenomena in any other light. For fear of our being similarly hampered by the words "electric displacement" and "electric current," I think it worth while pointing out that just as these words presuppose an analogy between electric quantity and volume of liquid, and electric potential and pressure of liquid, similarly it is quite possible to draw another analogy, namely between electric quantity and entropy, and electric potential and temperature, so that, with these two different analogies in view, it may be the less likely that the student should look upon either as anything more than an analogy, until further investigation shows that there is either a real likeness to one or the other, or that the electric phenomenon is *sui generis*, and unlike either, which latter is in my opinion the more probable supposition.

LVI.—ON AN HEXACTINELLID SPONGE FROM THE GAULT,
AND A LITHISTID FROM THE LIAS OF ENGLAND.
By PROFESSOR W. J. SOLLAS, M.A., D.Sc. (PLATE
XXI.)

[Read, February 16, 1885.]

Fossil sponge remains are exceedingly rare both in the Lias and Gault deposits of Europe. Fragments of sponge-skeletons and scattered spicules have been described from Liassic strata in Austria, and occasional spicules are met with in the English Lias; but hitherto no entire sponge.

The Gault of Cambridge contains not uncommonly so-called "coprolites," which have every external appearance of sponge-remains, but which on the other hand are usually devoid of internal structure.

The discovery by the Rev. P. B. Brodie, M.A., F.G.S., of two complete and sufficiently well-preserved sponges, one from the Lias and the other from the Gault of England, is consequently of considerable interest; Mr. Brodie, recognising this, has placed his specimens in my hands for description, and I now offer the following account of them, commencing with the specimen from the Lias:—

PLATYCHONIA BRODIEI (sp. n.).

Sponge, irregularly pouch-shaped; higher on one side, which is 55 mm. in length, than on the other, which measures 23 mm. in length. Central cavity large, 31 mm. across. *Wall* of slightly variable thickness—about 8 mm. where highest, and 10 mm. where lowest: both surfaces uneven, with irregular elevations and depressions; otherwise smooth. *Ostia* small; on the outside, from about 0.1 to 0.15 mm., round or oval; on the inside, 0.1 to 0.4 mm. in diameter, round, oval, or irregular; without a raised margin, even with the surface.

Canal System. Fine and irregular. Small canals rarely enter the wall perpendicular to the surface, and, when they do so, lose themselves in the interior. No vertical tubes.

Skeleton. Small, slender rhizomorphous corpuscles, arranged upon no evident plan.

Horizon. Marlstone, Lias.

Locality. Ilminster, Somerset.

Remarks. The form of the sponge is such as would be produced by the incurving growth of a lobate fan-shaped expansion to form an irregular cup. The highest part of the cup represents the median line of the fan, the lowest part the united edges. An incrustation of oolitic rock covers the surface in places; but, when this is absent, a dark-brown ferruginous layer is evident, in which, however, no structure such as might indicate the presence of a special dermal covering layer is discernible. On treating the surface with acid the ostia are rendered visible, as round or oval areas, bounded by the skeletal corpuscles in characteristic Lithistid fashion. They are not quite so well defined on the inner surface of the wall, and, though oval and round in most cases, appear there sometimes as quite irregular spaces.

The originally siliceous skeleton has been entirely replaced by carbonate of lime, and the structure of the nodes of the skeleton where interlocking occurred is completely obliterated. The corpuscles do not offer any characters which can be made use of for the discrimination of the species. Several sections of *Milliola* occur in the adherent rock-material.

CRATICULARIA CALATHUS* (sp. n.).

Sponge, vasiform or funnel-shaped, with undulating margin, slightly expanded above; tapering below to form a short stem, which ends abruptly in an oval scar; no evidence of attachment; height, 51 mm.; maximum diameter, 60 mm.; minimum, 36 mm. *Wall* of nearly uniform thickness, 6 to 7 mm., rounded at the edge, on the outside without ostia, on the inside bearing ostia arranged in vertical and horizontal rows more or less at right angles to each other.

Ostia apparently oval, elongated longitudinally; in a horizontal row 6 occur in a distance of 9 mm.; in a vertical row 5 in 12 mm.

Skeleton. Nodes not thickened, and imperforate.

* κάλαθος, ὁ, a basket.

Horizon. Lower Gault.

Locality. Cambridge.

Remarks. Of cretaceous sponges this most nearly resembles *Craticularia vulgata*, Pocta, and *C. zitteli*, Pocta, but differs partly in shape, since it does not expand at the base, as both these sponges do, and partly in the size of the oscules, which, judging from comparison with Pocta's illustrations, are larger than those of *C. vulgata* and smaller than those of *C. zitteli*. The inner surface is, however, very similar to that of *C. vulgata*. The skeleton, or what indications remain of it, appears to have been characterized by much slenderer or thinner fibres than occur in Pocta's species. The sponge is mineralized with iron pyrites, in the far from common form of simple octahedra, the faces, edges, and quoins of which project in all directions from both surfaces. In the interior, as shown by slicing, other faces as well as those of octohedra occur; they are striated in a marked manner, and may indicate the presence of marcasite.

The radial canals are nearly all filled with pyrites, but some for a short distance remain vacant, running straight across the wall. The skeleton has disappeared; its traces remain as hollow casts, which are only visible here and there; they may be distinguished from accidental cracks by their parallel-sidedness, rounded surface, and sometimes by their regular rectangular cross-like form.

I believe this is the first instance not only of the description of a fossil sponge from the Gault, but of the observation of traces of skeletal remains in a wholly pyritized specimen.

[*For Explanation of Plate, see next page.*]

EXPLANATION OF PLATE XXI.

Figs. 1 to 3—Illustrations of *Craticularia calathus*.

Fig. 1.—Hollow casts of fragments of hexactinellid network, seen by reflected light. Obj. 1 inch; oc. No. 2.

„ 2.—The sponge. Nat. size.

„ 3.—One half of the sponge, showing the oscules of the interior.

Figs. 4 to 5—*Platychonia brodiei*.

Fig. 4.—Section through the sponge, showing the skeletal network.

„ 5.—One half of the sponge, showing a longitudinal median section. The highly shaded portion indicates the matrix, which partly fills up the interior of the sponge.

„ 6.—The sponge. Nat. size.

LVII.—NOTES ON SOME POINTS IN THE CONSTRUCTION
OF TURRET CLOCKS. BY HOWARD GRUBB, M.E.,
F.R.S.

[Read, March 16, 1885.]

ALTHOUGH not exactly in my own line of work, I have lately had occasion to construct a turret clock, and having been thereby led to investigate somewhat closely the details of same, I beg leave to submit a few notes on those points in which I found it desirable to depart from the generally established lines.

1st. Considering the care that is always taken by the best makers to preserve the going parts of the clock from all unnecessary vibrations and shocks, by providing the most substantial foundation and isolating the clock supports from all floors, &c., it has always been a matter of surprise to me that they invariably, as far as I know, mount the "going" and striking parts on the one frame or castings. In the act of striking, the frame receives violent blows from the hammer levers, far in excess of anything likely to occur from other causes, and as no attempt is made to isolate this necessarily heavy rough part of the work from the delicate going part, it appears to me that these concussions must exercise a very bad effect on the rate of the clock.

I therefore have constructed the going and striking parts as entirely separate pieces of machinery, and they will be mounted on independent supports isolated from one another. The "going" portion alone is exhibited here to-night. The striking portion is too large and heavy to bring down with any convenience.

2nd. While my slight experience induces me to believe that Dennison's (Sir E. Beckett) double three-legged gravity escapement, which I have adopted in this case, is the very best for the purpose, I cannot believe with Sir E. Beckett that it is so perfect that to add a remontoire train is superfluous, and I have therefore done so.

Bearing in mind also that Sir E. Beckett himself says that the very best rate he ever knew in any clock is that at King's

Cross, London, which had an ordinary pin-wheel escapement with a remontoire train, I have so arranged the frame of this clock that I can in a few minutes replace the gravity by such a pin-wheel escapement.

Sir E. Beckett justly observes that crucial experiments on the rate of a clock can only be conducted when the clock is erected in its own permanent position.

I have therefore made arrangements to enable this clock, when erected at Farmley, on the far side of Phoenix Park, to automatically report its rate daily to me in Rathmines, and hope by this means to be able to form in some months a fair estimate of the value of the different kinds of escapement.

3rd. The remontoire fan usually applied to turret clocks, which has always appeared to me a very cumbersome and awkward piece of apparatus, I have replaced by a little fractional governor, similar to what I use for equatorial clocks.

I find this to work in a most satisfactory manner, and the whole apparatus is enclosed in a box two and a-half inches diameter, while the fan necessary to effect the same purpose would be at least two feet diameter.

4th. I have replaced the usual ratchet, which makes such a disagreeable noise every one-third or one-half minute, by a peculiar silent click, which is perfectly effective and absolutely silent.

In other respects the clock has no peculiar feature, except that its general arrangement is somewhat novel, and considering that it has to work two eleven feet exposed dials, and start the striking part, which rings a peal of bells, the largest of two tons weight, the escapement action is probably lighter than any hitherto made.

The pendulum is a two-second pendulum. All the small pinion in clock train are lantern, the smallest being made on the principle described by me on a former occasion with reference to Siderial clocks.

The "letting off" of the striking part is somewhat peculiar. The letting off cams are set up and placed in position by a slow moving shaft, but the final letting off is effected by a cam on a quick moving shaft, something after the manner of the Westminster clock.

LVIII.—NOTE ON THE PARTURITION OF A WEST-INDIAN
BAT. By HENRY A. BLAKE, GOVERNOR OF THE BAHAMAS.

[Read, March 16, 1885.]

ON the 2nd June, 1884, when inspecting the caves on the western shore of New Providence Island with Mr. Maynard, an ornithologist from Boston, and Mrs. Maynard, we observed the dome-like roof covered with pendent bats, of which there were about a thousand. We shot ten with our collecting guns, and on picking them up we found that eight had young ones clinging to them. The eyes of one or two were open, though the down had not begun to form, but the remainder had the eyes still closed. On our return, when taking them out of the basket, I found that one of the full-grown bats was a female, apparently unwounded, but so heavy with young that it had fallen down with the concussion and been unable to rise. As I was informed that the manner in which bats were born had never yet been observed, and was a matter of scientific interest, I placed the bat in a box about eighteen inches high, with a glass front and wire top, and watched it closely. It hung to the top, where it remained all night. At noon on the 3rd, I observed that the exclusion of the young had commenced. The bat had been hanging by one hind claw for several hours, the other being bent forward at right angles. There were regular labour paroxysms at intervals of about two minutes, lasting for about four or five seconds. Sometimes it hung by both claws, and bent back or forward, evidently suffering much. At 12.20 the left hind leg of the young bat entirely protruded, being doubled forward at the second joint. Almost the entire time the mother hung by the right hind claw, using the other to scrape from time to time the membranous sac in which the protruded leg was enveloped, or to scrape herself as a relief to the tension. As soon as the left leg of the young had been protruded the mother scraped the sac until it broke, when immediately the protruded leg was straightened and the claw grasped the integument of the mother's "wing." The latter

hung by the right leg, and bending the left forward, on this the free leg of the young was forthwith hooked. This evidently assisted the mother materially in its exclusion, as she gently raised the bent leg during the active periods of labour pains, thereby drawing the young one upwards. At 12.30 the other leg was free, and immediately both legs grasped the mother. At 12.35 it was completely excluded, the back of the head to the front, so that at once it clung round the mother with wings and legs. The latter licked it all over, and continued to do so for half an hour. The ears of the young bat were all this time folded flat on the head. The eyes were closed. The mother then began to bite at the umbilical cord by which it was still attached, resting at times as if exhausted. She continued this until half-past one, biting away small portions. At 3 p.m. the young was still attached by the umbilical cord, but was apparently sucking the mother. I was unable to observe anything further until 10 p.m., when on looking at the bat I saw that the placenta had just come away and was being eaten by the mother, who let nothing fall.

Mr. Maynard, who examined the bats, stated that they were a variety hitherto undescribed. There were six of the young bats alive, and I had them fed with milk, which they sucked from the finger. However, they all died. On Wednesday, 4th June, the bat whose birth I had observed died. It was evidently trying to obtain nourishment from the mother, but was unable to do so. Sometimes it seized the mother's wing—sometimes close to the vent. The mother seemed unable to place it on the teat; indeed, it grasped so tightly and with such pertinacity that the mother could not move it from any position in which it chose to place itself. On one occasion it seized the mother's ear, and there it remained for an hour. After its death the mother adopted one of the other young ones, but it died also. I examined the mother most carefully, but could not find a vestige of a teat anywhere. She is still alive, and eats sapodillo pears greedily. The head of the young is singularly like a pig. I have preserved a couple in spirits, which I shall forward to the Science and Art Museum, Dublin.

So far as I know, the bat is the only mammal produced with the hind feet first presented. The manner of its birth is a singularly interesting illustration of the modifications effected by Nature to meet peculiar conditions.

LIX. — REMARKS ON THE GAMETOPHORE OR OOPHORE
STAGE OF VEGETABLE METAGENESIS. BY
PROFESSOR W. R. M'NAB, M. D., F. L. S., &c.

[Read, April 20, 1885.]

IN the English edition of Sachs' *Text-Book of Botany* the two stages of the Alternation of Generations in plants are denominated the Sporophore and the Oophore, respectively; the former being the spore-forming generation, the latter the sexual stage. While the term sporophore accurately expresses the conditions in the one stage, the term oophore is only applicable to one of the sexual forms, and is, therefore, open to objection, although that one happens to be the more important of the two. In view of the great importance of having an intelligible and easily applied series of names for the reproductive organs of plants, it is advisable to re-consider the whole matter, and the reasons for doing so are all the more cogent because recently the subject of the sexual reproduction of the lower plants has received a great deal of attention, and several new terms have been coined. No general set of terms has as yet been agreed upon by botanists; and as the reproductive organs have the greatest possible diversity of origin and construction, very many names have been used, limited to special cases, but none of general applicability. Sachs has well pointed out that in the case of the vegetative organs of plants there is the same plan of construction associated with the utmost diversity of function; but that in the reproductive organs this is reversed, and identity of function is attended with great diversity of structure and mode of origin (Sachs, *Vorlesungen*, p. 886).

The term *gamete* has been long employed to signify the sexual cells of the lower forms of plants, and, by continuing to use this term, we can by prefixing *andro-* and *gyno-* indicate the male and female reproductive elements as *androgametes* and *gynogametes*. These terms seem to me to be very much to be preferred to those used by Sachs, namely "zoosperms" and "egg-cells" (*Vorlesungen*, p. 887); because in many cases the male element is not a "zoo-

sperm" comparable with a spermatozoid, and the female cell is not always an "oosphere."

If, then, we accept the terms "androgamete" and "gynogamete," the union of the two can be defined as "zygosis," and the product a "zygote" or "ovum," both these latter terms being already accepted by botanists. We can thus indicate the essential part of the sexual process—the union of the male and female elements, protoplasm with protoplasm, and nucleus with nucleus—as zygosis; and we can easily distinguish any preliminary steps in the whole process of fertilisation; as, for example, in the higher flowering plants, where pollination, or application of the pollen, precedes the process of zygosis, if the actual fusion of the reproductive elements can be held to occur in all cases. It is important to note that the term "ovum" must be regarded as the exact equivalent of zygote, the ovum being the new cell formed by the union or conjugation of one or more androgametes and the gynogamete.

Passing one step further, we may now indicate the cases in which the male and female sexual elements are formed as the *gametangia*, a term already used and adopted, and we can at once distinguish between the *androgametangia* and the *gynogametangia*. The structure of these two organs varies very much, and we have the antheridium as the typical androgametangium, and the archegonium as the typical gynogametangium. Sachs (*Vorlesungen*, p. 887) proposes to use the terms "spermogonia" for the male organs, and "oogonia" for the female; but both these terms are quite inadmissible, the word spermogonium having been applied to special structures in the Fungi and Lichens, which are now known to be non-sexual, and the word oogonium is in common use, and is merely a rudimentary archegonium.

If we now take the plant that bears the gametangia, it is easy to denominate it the *gametophore* (a term I have now used for some time); and in such instances as in the prothalli of *Equisetum*, where the male and female organs are produced on different plants, the two plants can be called the *androgametophore* and the *gynogametophore*, respectively.

As we can thus obtain a perfectly consistent set of terms, without really adding to the burden of botanical terminology, I would strongly urge the rejection of Mr. Dyer's term "oophore," as it is only applicable to the plant bearing the fertilised ovum.

It will further be seen that for the non-sexual stage we have now in use a set of terms—spore, sporangium, sporophore—terms universally accepted, and the words gamete, gametangium, gametophore, would, if adopted, at once indicate a similar series of relationships in the sexual stage of development.

But we can advance one step further, and distinguish between reproduction by spores and reproduction by buds, and attempt to solve that most difficult botanical question, as to what is a spore. It is quite obvious that the spore must be associated with a spore-case or sporangium, and in all instances in which several spores originate in a spore-case no difficulty can arise, and there can be no such things as endoconidia. It is, however, quite different when only one spore is produced in a spore-case; but here we invariably find that the spore either develops a special wall inside the wall of the sporangium, or else the spore escapes as a naked mass of protoplasm, and only develops a wall at a later stage. Now, if we apply this character to many of the reproductive bodies of the lower plants, we find that the different forms of conidia are all single detachable cells, without that inner wall which would indicate the formation of a spore inside a sporangium. Conidia are thus buds which become detached from the parent plant. Usually among the Fungi both spores and conidia are formed, there being often several kinds of conidia developed by one plant. As gamogenesis is exceedingly rare in Fungi, the reproduction is either by spores or conidia, or by both, as in most of the Ascomycetes. A question will arise as to the so-called spores of the Basidiomycetes. As they arise like conidia,¹ and produce no special internal wall inside the special swelling of the end of the sterigmata of the basidium, I believe we must regard them as a group of Fungi which have lost the power of producing spores and only multiply by conidia. This is the last step in development in the Fungi, as it is only in the lower forms that sexual reproduction exists, and even in them apogamy or parthenogenesis becomes marked. Thus true alternation of generations ceases and we have multiplication by spores or by conidia, the conidia alone remaining (Basidiomycetes); or the spores are only produced under exceptional conditions, as in *Penicillium* and other Ascomycetes.

¹ See Vines. Prantl's Text-Book of Botany, p. 141.

All these modes of non-sexual generation which cannot be included under the head of sporogenesis I would distinguish as *blastogenesis*, and the special reproductive bodies as *blastidules*. These blastidules are very varied, and appear as conidia, propagula, gemmae, buds, or even as fragments of a large plant.

The reproduction of plants is thus of two kinds:—1, gamogenesis, or sexual reproduction; and 2, agamogenesis, or non-sexual reproduction. Agamogenesis appears under two forms—namely, sporogenesis and blastogenesis, and when there is metagenesis, or alternation of generations, it is an alternation of gamogenesis and sporogenesis. Blastogenesis may occur both in the sporophore and gametophore stage, and numerous examples might be given. Then gamogenesis may be absent, and the plant may reproduce by sporogenesis or by blastogenesis, as in most Fungi.

Lastly, as we have in such forms as *Ulothrix* and others multiplication sometimes by gamogenesis, sometimes by agamogenesis, the sexual cells which have failed to form zygotes often developing by themselves non-sexually, thus giving us intermediate forms between sexual cells and spores; so we may expect to find that there are intermediates between spores and blastidules.

LX.—ON DE ROSSI'S SEISMICAL AND ENDODYNAMICAL
MAP OF ITALY. BY PROFESSOR J. P. O'REILLY,
C. E., M. R. I. A.

[Read, May 15, 1885.]

It would not be too much to say that the particular branch of geology which deals with the forces acting from within the earth's surface, and tending to modify it, has assumed within late years a very great importance; so much so, that under the name of Seismology, Dynamic Geology, Endodynamic Geology, it has attained the rank of a specialty in connexion with Geology, and has led to observations and methods of observation of the very highest interest and importance. In Germany, in Switzerland, in Italy, in America, and in Japan, societies have been formed mainly for the study of phenomena coming under this head, and certain of their results seem to me well worthy of being more generally made known.

The full value of the earthquake as a factor in Geology can hardly be considered as having yet reached a clear and distinct recognition. So many things in this phenomenon have to be accounted for, and their systematic observation is attended with such great difficulties, and even dangers, that such incomplete recognition of their importance can easily be explained. Besides, earthquakes, up to the present at least, can hardly be foreseen, or only exceptionally, as in the case of the neighbourhoods of Vesuvius and Etna, where seismic observatories are established and under the conduct of skilled observers. That there are premonitory indications in nearly every case is to be presumed; but as regards the great majority of recorded shocks, data of this character are wanting. And yet the consequences of earthquakes are such that the very greatest interest attaches to the correct observation and interpretation of the phenomena which precede them, and which, rightly read, are capable of serving as indications of a coming shock.

Palmieri at Naples, and De Rossi at Rome, have long occu-

pied themselves with this question ; and De Rossi, in a very remarkable address, delivered before the Geographical Society of Rome, in February, 1882, on his then projected seismical and endodynamical map of Italy, enters into very interesting considerations on this point, to some of which I shall take occasion to call attention.

One of the most frequently-cited observations in connexion with earthquakes, at least within the last century or so, is the state of the barometer before and after the shock. It is frequently recorded that the barometer was low before the earthquake cited, and a sudden fall has come to be construed, at least for certain localities, as an indication of an impending shock. Such an interpretation of the fall necessarily implies a connexion or relation between the atmospheric pressure at the place considered and the state of equilibrium of the tensions existing in the constituent matter of the earth underneath that place. Are there any grounds for assuming the general existence of such a relation ? I believe there are. The atmospheric pressure at any one place is simply the measure of the attraction exercised by gravity on the atmosphere at the place ; that is, by the mass of the earth. Any variation in the distribution or arrangement of this must in some sort alter the position of the centre of gravity of the earth, however minutely, and should have, as consequence, a corresponding alteration in the amount and direction of the attraction exercised on the atmosphere, and therefore in the atmospheric pressure over different parts of the surface of the earth. Now, tensions which exist under a given surface, and which increasing and tending to reach a limit, and therefore of a nature capable of giving rise to an earthquake, must affect the arrangement of the matter of the earth under that surface, and *pro tanto* are capable of affecting the attraction of the earth for the atmosphere at the place considered, and consequently the pressures.

But, even admitting this relation, the difficulty lies in the measurement of the amount of pressure attributable solely to alteration in the amount of attraction exercised at a given point of the earth's surface. We have but one instrument for estimating atmospheric pressure, that is, the barometer, and it really only gives us the resultant of *all the forces*, whatever they may be, which act on the atmosphere at the point of observation, without discrimination of the components. Furthermore, when a barometric

observation is made, it is always assumed that the atmosphere is in a normal state as regards its constitution, at least for those altitudes of which we have some knowledge. But that is simply assumption, and the constitution may be abnormal at a given time and for a given locality; and that such frequently occurs immediately before earthquakes may be gathered from some of the facts recorded as having preceded many earthquakes, and which have not, perhaps, received the full amount of attention which they merit. Thus there is frequently made mention of indications of uneasiness, more or less marked, on the part of certain classes of animals, more particularly of those which, by reason of their size or their habits, are naturally brought into close contact with the earth, such as small quadrupeds, fowl, cats, dogs, snakes, &c. Now this may fairly and reasonably be attributed to the emission of gases of a nature hurtful to such animal life, such as carbonic acid, certain carbides of hydrogen, hydrogen itself, or even sulphuretted hydrogen, all which are intimately associated with volcanic and seismic manifestations. This view is strengthened by the frequent alterations reported as occurring before earthquakes in springs and streams, such as their drying up or disappearing by reason of joints or fissures presenting an easy escape for gases which may be imprisoned in depths, and the excessive pressure of which is a main cause of many if not of most earthquakes. How long before the earthquake may such escapes of gas have been going on on a minute scale, hardly, if at all noticeable, is a question of much interest, and would point to the importance to be attached to the careful examination of the waters of springs, particularly if they have their sources in districts at all affected by earthquakes. The well-known variations in the volume and temperature of already existing hot-springs consequent on earthquakes justify this point of view as well as the equally well-established rôle of these in giving rise to such springs. We can thus see that there is an intimate relation to be recognised between earthquake action and emission of gases, and between these and fissuring or jointing. Now, the tendency of all recent seismic research and observation is to connect earthquake action with the existence of systems of jointing and fissuring. And thus we have a relation established between these emissions of gases and earthquakes. But such gases, by reason of their specific densities and temperatures of emission, influence more

or less the barometric pressure at the place of their source. Of small quantities given off probably no account could be taken, since their influence on the barometer would be insignificant; but for great quantities of gases given off the effect would be all the more marked, proportionally to the volume, temperature, power of dilatation, and lowness density of such gases, since ascendant currents must then arise with consequent fall in the barometer. Therefore there may be cases where a fall in the barometer would really and truly serve as an indication of an impending earthquake, but would also imply an escape of gases on a very large scale. This connexion goes far to explain also many manifestations frequently recorded as following on or accompanying earthquakes, such as sudden whirlwinds or local storms, great electrical tension and display of lightning, balls of fire or meteors, and even the so frequently-mentioned seasons of disease or bad harvests, since great quantities of noxious gases thus poured out from the earth would necessarily saturate the pores of the earth, be retained there, and consequently influence both vegetable and animal life. We know little yet as to the constitution of the atmosphere at heights such as 10,000 m. above the sea level, or even, indeed, between 8000 and 10,000 m.; but it has been distinctly ascertained that the quantity of ammonia increases with height, while the carbonic acid decreases; and we may therefore assume that hydrogen and the volatile carbides of hydrogen increase in quantity also with height where they are subjected to the action of electricity and solar action, giving rise thus to combinations accompanied by emissions of light such as to present the appearances of meteors. Is there not some similarity between the conditions presented by the highly rarified atmosphere at those heights and those presented by the vacuum tubes experimented on by Crookes, by means of electrical currents?

This idea of foreseeing earthquakes, by the careful observation of all the phenomena connected with them, is one involved in De Rossi's proposed seismical and endodynamical map of Italy. In the address alluded to he commences by calling attention to one of the results of his studies, that is, "that we always find a certain identity as regards the manner and the quality or energy of action of all the earthquakes which in the course of time have affected or affect a given locality; whence follows the possibility of affirming that with the aid of certain geological and orographical

observations, the seismical topography of any district may be traced out beforehand." Further on he says: "The want of a seismical and endodynamical map of Italy soon made itself felt, once the new methods of seismical study were initiated, and which consist essentially in a great chronological and topographical co-ordination of the history of the dynamo-geological phenomena having affected our country, and in a similar co-ordination of the continuous observations made of the sensible as well as insensible manifestations of internal dynamic action."

He alludes to the maps which have been frequently published, showing the actions of earthquakes in certain countries and districts, and states: "One thing alone constantly appears on these maps, the perimeter of the surfaces shaken always presents an elliptical form. My manner of understanding this elliptical form of the area shaken," he says, "is that the centre of percussion tends to assume a lineal form; or, as Serpièri so well expresses it, the seismical centre assumes the form of a radiant (*radiante*). This radiant would consequently be the major axis of the ellipsis."

He calls attention to Ponzi's studies "as pointing to the fact that geological fractures of the earth (*suolo*) are the means of communication of the endogenous cause of earthquakes, and act as lines of interruption to the uniform propagation of the seismic wave."

Wishing to verify by actual observation the truth of this result, he took occasion to map out the effects of the earthquakes which affected the country near Rome in January, 1873, "wishing to profit by the occasion to make an accurate study of the relations which came to be established between the well-defined geological fractures of the volcanic system of the district and the form of the earthquakes having occurred. I saw that in each case it was evident that the fracture had acted as a seismical radiant, and that by tracing out the map of the volcanic fractures I at the same time traced the axes of propagation of the seismic undulations. It was then that I formulated the mechanical law of earthquakes, well known to all, according to which the seismical wave is, in any given country, always first parallel and then normal to the axis of the nearest system of geological fissuring (*secondo la quale l'onda seismica in ciascuna contrada è mai sempre parallela prima, e poscia normale all'asse della fenditura geologica più vicina*).

Whence I formulated the axiom, never sufficiently repeated, because it is the basis of the new architectonic precepts preservative against the action of earthquakes—*The shock communicated to a line of fracture is followed by the transverse oscillation of its sides or margins.*”

Serpieri took advantage of the great earthquake of 12th March, 1873, to thoroughly control the observations of De Rossi, and the result was the most complete confirmation of the laws established by De Rossi on the propagation of earthquakes by the fractures with waves parallel and normal to the axis of the systems of fracture.

This earthquake of 12th March, 1873, was mapped by Captain Gatta, and from this map there resulted “that the central zone coincided with a long lineal tract of the axial crest of the Apennines, and that the arrows (of direction of wave) parting all from this crest, assumed directions along the two slopes parallel to the axes of all the valleys of the rivers. It is a most notable thing that nearly all the valleys of the Apennines are thus shown to be geological fissures dividing the masses of the mountain chain.”

Further on he says: “The fissures of the earth wherever met with represent a series of abscisses and ordinates. It is clear that where the seismic agent breaks out it should propagate itself with greatest violence and rapidity in the direction of the fissure that it penetrates.” Thence it propagates itself into the lateral fissures, which thus become derived or secondary radiants. So that in some sort the zone affected presents somewhat the appearance of the backbone of a fish with the spines, “round which if a perimeter be traced it assumes the form of an ellipsis.”

“My map (p. 8), although very imperfect, shows a system of coincidences between the geological fissures and the seismic radiants which cannot be fortuitous, and which, therefore, is in itself a demonstration of its scientific truth.”

“It has been already shown that my seismic map is equivalent to a map of the geological fractures or fissures; but it may be observed that it is at the same time in some sort a hydrographical map of Italy. Whence it follows that the main lines of the geological and orographical structure of Italy, of its hydrography and its seismic lines of works, become identified, or at least are brought into very close connexion.”

He considers (p. 9) that the seismical map is not sufficient for the objects of his studies, which must be extended to all the phenomena having an origin internal to the surface of the earth, in order "to prepare from them a synthesis which will reveal the secrets of telluric dynamics—of that telluric dynamics up to the present so very little studied and not at all known, although it covers so many menaces for our very existence as well as innumerable aids to our prosperity."

Speaking of Pella's definition of an earthquake as an attempt, or unsuccessful effort of eruption from the interior of the earth, he says: "As a matter of fact, there never is a volcanic eruption without earthquakes, nor is there an earthquake, even in non-volcanic regions, without eruption or at least emission of gases and vapours."

Having alluded to microseismical movements and their micro-eruptions, he says: "In one word, the subterranean circulation of water is to be considered as a factor of the first importance in the incessant labour of the internal agents of the globe."

Speaking (p. 12) of the method which he proposes to employ for the co-ordination of his work:—"The system of division, the best appropriated to the scope of my undertaking, is that of considering separately the hydrographic basins of Italy. This division, from what has been already explained, leads mechanically, so to speak, to tracing out the network of the fissures and of the seismic radiants, and to defining the axes of the valleys, along which will be found the secondary manifestations of activity, the thermal springs of the present, and the geological traces of a telluric action which has ceased to show itself."

He shows (p. 13) that the surface hydrography of the country is intimately connected with internal telluric action, and adds: "If the valleys are in the most cases fissures of the earth's crust (*suolo*) they must, consequently, be the passages by which absorption of the surface waters takes place, so as to reach directly the internal laboratories and join the subterranean system of circulation."

Alluding (p. 14) to the frequency of earthquakes in and about the Lago di Garda, he states: "The most recent geological researches have demonstrated that the lake is an immense geological fissure. The courses of the great rivers are very frequently the axes of earthquake shocks. Whence," he says, "the study of the

hydrography of a country is equivalent to the study of what may be called the keys of the internal telluric activity." He adds (p. 15): "The tempests and the extraordinary storms, the centres of barometric depressions which have sojourned more or less in a river-basin, will be found to be phenomena proper to each particular basin, and capable of influencing its endogenous activity."

Referring to the importance to be attached to the examination of precipices and cliffs as connected with fissuring, and thus with former earthquake-action, he says (p. 15): "Taramelli with good reasons thinks that in a post-glacial epoch, but pre-historical, the surface of Italy was subjected to an extraordinary endogenous activity and to seismic convulsions far greater than those known or recorded in historical times, and that at that period were produced the great fracturings, having giving rise to cliffs, and the consequent incumbering of the valleys of fracture with detritus, and to alterations in the regimen of the hydrographical basins."

With these phenomena he connects that of the formation of travertine, and considers that both together point to an immense development of endogenous activity during the post-glacial period, which also was that of the littoral volcanoes of Italy; so that the littoral vulcanism and its secondary and inland manifestations correspond to a same geological era.

LXI.—ON THE STRUCTURE OF THE FLOWER OF *BONATEA SPECIOSA*, WILLD. By W. R. M'NAB, M.D., F.L.S., Professor of Botany, Royal College of Science, Scientific Superintendent of the Royal Botanic Garden, Glasnevin; and Consulting Botanist to the Royal Dublin Society.

[Read, May 18, 1885.]

ON the 29th of April, 1885, Mr. F. W. Moore directed my attention to a plant of *Bonatea speciosa*, Willd, then in flower at the Royal Botanic Garden, Glasnevin. The plant is a native of the Cape of Good Hope, and the specimen in the Glasnevin Garden was obtained from the Leyden Botanic Garden in 1883. As the flower was evidently one of great interest, Mr. Moore kindly sacrificed the whole spike, and I have since examined the structure carefully. On making a direct examination of the flower, without having consulted any book or paper on the subject, I came to the conclusion that in the flower of *Bonatea speciosa* all the typical parts of a monocotyledonous flower were represented, and that therefore the plant was one of singular interest. The three parts of the calyx, the three petals, were present as usual, as well as the one fertile stamen of the outer row. But, in addition, there were two petal-like structures, but more conspicuous than the petals, and these I at once considered to be petaloid staminodes. Next, two gland-like structures attracted my attention, at the base of the staminodes, and these were put down as representing two of the inner row of stamens, and a conical fleshy projection on the labellum immediately in front of the spur completed the inner series of stamens. The rostellum and two fertile styles and stigmas projected outwards over the labellum, and thus completed the flower.

Bonatea speciosa was carefully studied by Darwin from dried specimens (see *Fertilization of Orchids*, p. 302, *et seq.*), and he considers *Bonatea* to be an exception in regard to its structure; but he considers the wide separation of the anther cells to be the cause of the distortion. He also holds the view of all descriptive botanists, that the lateral petals are cleft into two. Further, he points out

two anomalies in the supply of the vessels to the different parts. Those are: first, that the vessels which supply the sides of the upper sepal enter the postero-lateral or paired petal bundles; and, secondly, that the vessels to the anterior side of the upper petals enter the antero-lateral or paired sepal groups.

I have examined both longitudinal sections of the flowers rendered transparent, and a consecutive series of transverse sections, and I am able to confirm Mr. Darwin's statement that the lateral sepaline bundles join the paired petal bundles. Ramification of the sepal bundles occurs, while the ultimate paired petal bundle remains unchanged after giving off the bundle to the sepal. It seems remarkable that the position of the bundle of vessels to the so-called anterior parts of the upper or paired petals should not have led Mr. Darwin to consider the structures to be staminodes, as they are in the proper position.

I can trace no vestige of bundles to the three rudimentary stamens of the inner row, if such they be, although I have specially searched for them.

In making sections of the inferior ovary, six bundles can be observed—three corresponding to the placentas and three alternating with them. Two of the placental bundles have each three minute bundles on their inner side, and the third, corresponding to the labellum, has two large bundles. These eight small bundles quite disappear in the upper part of the ovary, and the shortest placenta is that corresponding to the position of the labellum. We thus have in this Orchid flower three bundles which have to supply the placentas, and three that do not. The bundles supplying the placentas must be called upon to supply water and much nutrient matter to the growing ovules, and their development in the flower above must be hindered. Hence, as they correspond to the *petals*, the petals will be feeble in Orchid flowers, and the stamens superposed to the petals more or less completely wanting. On the other hand, the sepaline bundles are well developed, and they give off bundles to the fertile stamens and lobes of the stigma, the bundles to the stigmas being given off very early before those to the lateral stamens. The Orchid flower is much developed anteriorly and posteriorly; but the posterior petal, the labellum, cannot get much nourishment from a bundle which has to supply the placenta, and therefore its supply must be supplemented. In the leaves of mono-

cotyledons the bundles entering the leaf are directly proportional to the circumference of stem occupied by the leaves, and to the number of bundles in the stem. In the Orchid ovary the posterior part is flattened in *Bonatea*, and this evidently permits an additional supply of nourishment to be obtained from the more vigorous lateral sepaline bundles, the petaline bundles not even being able to send off a filament to the extremely reduced structures in the flower which obviously represent two at least of the inner verticil of stamens. Thus, many of the peculiarities of the Orchid flower probably depend upon the vascular supply, and this subject is one that will certainly well repay further careful research.

The flower of *Bonatea speciosa* is well described and figured by Mr. Roland Trimen, in *Jour. Linn. Soc.*, vol. ix., p. 156; but he gives no critical remarks on the structure of the flower.

LXII.—ON APOSPORY IN THE THALLOPHYTA. By W. R. M'NAB, M.D., F.L.S.; Professor of Botany, Royal College of Science; Scientific Superintendent of the Royal Botanic Garden, Glasnevin; and Consulting Botanist to the Royal Dublin Society.

[Read, May 18, 1885.]

MR. DRUERY's remarkable discovery of Apospory (*Journal of Linn. Soc.*, vol. xxi., pp. 354, 358, and 360) may help to explain certain peculiarities observed in the Peronosporæ and also in Vaucheria. As apogamy is not limited to the higher plants, it is therefore most natural to expect the occurrence of apospory in the Thallophyta. As apospory seems to be a very peculiar change occurring only under certain special conditions, it is not to be expected that the process will be common in the Thallophyta; and the two sets of examples here brought forward as apospory are both met with in highly specialized non-cellular plants, the one being a green Alga, the other instances being from a remarkable group of parasitic Fungi.

In *Cystopus candidus* there is produced below the epidermis of its host a moniliform series of cells, and the cells of this series may become separate when mature. These cells are almost always described as conidia. Van Tieghem (*Traite de Botanique*, p. 1021) simply calls them spores, while Vines in the fourth edition of Prantl's Botany calls them sporangia. That they cannot be conidia is abundantly evident from the fact that the contents escape as ciliated zoospores; while conidia seem always to germinate directly, by sending out one or more tubular prolongations. By comparing the closely allied genus *Achlya* with *Cystopus*, the necessary proof seems to be obtained of the identity of the zoosporangia of *Achlya* with the so-called conidia or spores of *Cystopus*. The single terminal bodies of *Peronospora*, and the somewhat similar bodies in *Phytophthora* may also be regarded as true sporangia, although there is a special peculiarity in *Cystopus*; namely, that the sporangia are superposed to one another in a

moniliform series, a condition which, however, is also met with in the allied *Monoblepharis polymorpha*.

We may therefore regard the so-called conidia or spores in the Peronosporæ as detachable sporangia, dissociation of the sporangium and sporophore being of importance in the scattering of the ciliated zoospores which takes place under favourable conditions. Many modifications occur in the formation of the zoospores, as fully described by Van Tieghem (*Traite de Botanique*, p. 1022), and while in many instances zoospores are normally produced, under other conditions they are always wanting: while in a third series zoospores may or may not be produced. When the spores are not produced, and direct development occurs, we have undoubted examples of apospory. This is best shown in *Cystopus portulacæ*, and in *Phytophthora infestans* (Van Tieghem, *loc. cit.*). In *Cystopus portulacæ* the first and oldest sporangium of the moniliform series behaves differently from the others of the same series. The lower ones all develop as sporangia, and liberate zoospores; but the upper one does not liberate its contents, and sending out hyphæ, develops directly into a new thallus. This is an example of apospory. *Phytophthora infestans* exhibits apospory when the sporangia are grown in moist air, as hyphæ are directly produced; but zoospores are developed in the usual way when the same sporangia are placed in water. Lastly, in a number of species of Peronospora a single spore may be formed, and escape from the sporangium, after which it germinates in the usual way; or else the sporangium sends out hyphæ, and the spore is suppressed. This is seen in *Peronospora gangliiformis* *P. parasitica* and others: all of which are to be regarded as truly aposporous (see Van Tieghem, *Traite de Botanique*, p. 1022).

In *Vaucheria*, where the structure is in many points remarkably like that of the Peronosporæ, no question has ever arisen as to the propriety of regarding as a sporangium the cell, cut off from the rest of a thallus by a transverse wall, in which the zoospore is formed. There is in *Vaucheria* the most complete series of gradations, from the production of ciliated zoospores to spores which have no cilia, and do not leave the sporangium, to complete apospory in *Vaucheria tuberosa*. In this species all the phenomena associated with the formation of a sporangium are observed, but the isolated sporangium develops into a new thallus without

giving rise to a spore (see Van Tieghem, *Traite de Botanique*, p. 1133).

There seems to me to be some little difficulty in accepting Professor Bower's statement that the artificial production of protonema and buds from cut pieces of the sporangium of certain mosses is an example of apospory (see *Journal Linn. Soc.*, vol. xxi., p. 366). It much more closely resembles the production of conidia by certain Fungi under unfavourable conditions of growth, and is thus blastogenesis. No mosses seem to produce a leafy axis directly from a protonema developed by the ovum; but looking at the condition as possible, we may regard the development of the Characeæ as exhibiting apospory; and we can thus account for the absence of spores in this most remarkable group. In the Characeæ the fertilized ovum contains a rudimentary sporophore generation, which by apospory forms the prothallus and lateral bud from which the Chara plant arises. While thus regarding apospory as probably wanting in the Bryophyta, Chara may be looked upon as habitually aposporous.

In Batrachospermum (Van Tieghem, *Traite de Botanique*, p. 1185), where the spores (protospores, v. Th.) are suppressed, and the ovum gives rise directly to a protonema, we have also a probable example of apospory, and an analogy indicated with Chara and the Bryophyta.

The Peronosporæ, as we have just shown, exhibit apospory, and it is remarkable that the next group, the Saprolegneæ, exhibit apogamy, direct development occurring in many of them without the female cell being fertilized by the male cell. If, therefore, we have direct development without the formation of spores (apospory), and direct development without the formation of the gynogametes (apogyny), may we not also have direct development to a limited extent of the male, the androgametophore or androgametangium stage, and thus have apandry? (For further remarks on apandry and apogyny, see Van Tieghem, *Traite de Botanique*, p. 956.) If we regard the sexual stage of the plant merely as the oophore, we lose the significance of this development, where no androgametes are formed, and the androgametangium, or even the androgametophore, seems to develop directly. I would regard the remarkable development of the male reproductive stage in the pollen grain as apandry, and I would further consider that in the

Saprolegneæ there is apandry where the antheridium fuses with the oogonium, and no androgometes are formed (*Achlya*, *Saprolegneæ*, *Aphanomyces*). Those remarkable parasitic Fungi, the *Peronosporæ* and *Saprolegneæ*, are examples of apospory and apogamy, in its two forms apandry and apogyny.

It is possible that in such a plant as *Ulothrix*, where the gametes are similar, and where, as Dodel-Port¹ has shown, the gametes may develop directly without conjugating, both apandry and apogyny may be present. Indeed the whole subject of reproduction will require to be reconsidered in the light of such discoveries as those of apospory and apogamy.

Lastly, Professor Bower (*Journal Lin. Soc.*, loc. cit.) mentions the remarkable development of buds in *Isoetes* as an example of apospory. It appears to me that this process is more closely related to the production of buds in *Lycopodium selago*. The production of buds in *Lycopodium* is a remarkable process admitting of several variations; and it is at present very difficult to separate apospory from ordinary budding, leaves being so often sporophylla.

¹ Jahrb für wiss. Bot. x., 1876.

LXIII.—THE DISTRIBUTION OF THE STARS IN SPACE.

By W. H. S. MONCK.

[Read, May 18, 1885.]

THAT the fixed stars are not uniformly distributed in space is a fact too obvious to insist upon; but, nevertheless, I believe some important consequences may be derived from tracing the results of an uniform distribution, and then comparing these with the results of observation, and pointing out where the most remarkable deviations take place.

Supposing the stars to be all of equal absolute brightness, and to be situated at equal distances from each other throughout all space, it will appear that if we describe a sphere with the earth as centre, the light of the stars which intersect or touch this sphere will be a constant quantity; for the number of stars which intersect or touch the sphere will vary directly as the square of the radius, while the intensity of the light of each star will vary inversely as the square of the radius. This result will not be affected by giving to the surface of each sphere a small but uniform thickness; and by adding together a number of such surfaces it becomes evident that the total light of the stars comprised within any sphere will vary directly as the radius of the sphere—this radius measuring the number of surfaces of which the sphere may be considered to be made up. But the number of stars comprised within each sphere will evidently vary as the cube of the radius. If, taking any sphere as unit, we describe other spheres with twice, three times, four times, &c., its radius, the stars comprised within these spheres will give twice, three times, four times, &c., the light of the stars comprised within the inner sphere; whence it follows that the stars comprised in the space included between any two adjacent spheres will give the same amount of light as that of the stars in the inner sphere. Since the total number of stars in each sphere is proportional to the cube of its radius, the number of stars in these interspherical spaces is easily calculated. Representing the number of stars in the inner sphere

as unity, the number in the successive interspherical spaces will be 7, 19, 37, 61, &c., the general expression being $(n + 1)^3 - n^3$. Each of these sets of stars will (on the hypothesis of uniformity) give us the same amount of light.

One obvious consequence follows from the foregoing considerations. If the radius of the sphere becomes infinite, the quantity of starlight becomes infinite also. Strictly, of course, this could not be true. One star would get in the way of another, and there are probably a number of dark bodies in space which would intercept some of the light without giving any themselves. But after making a very liberal allowance for this kind of obstruction, the entire sky ought to glow with a brightness exceeding that of the full moon. There seem to be but two possible reasons why something approaching to this state of things is not found to exist by observation. The first is, that all the stars belong to one vast system occupying a particular region of space, and that beyond this region there is a practical vacuum. The other is, that there is some medium widely diffused through space which intercepts a portion of the starlight, and produces very sensible effects in the case of extremely remote stars. The motions of Encke's comet afford some reason for believing in the existence of such a medium, and other reasons will, I think, appear before the close of the present Paper.

If we suppose the inner sphere of which I have spoken to include twenty stars, these stars will, on the hypothesis of uniformity, be the twenty stars of the first magnitude recognized by astronomers. The second, third, fourth, &c., sets will consist of 140, 380, 740, &c., stars in the descending order of brightness, and the light given by each set of stars will be constant and equal to twenty, if we represent the average light of a first magnitude star as unity. Now, Dr. Ball, the Astronomer Royal of Ireland, in his *Elements of Astronomy*, has given us the number of stars of each magnitude from the first to the ninth, and also several determinations of the ratio of the light of the stars of any magnitude to that of the magnitude next above it—a ratio which appears to be nearly constant. This ratio has been variously determined, the figures ranging from 0.346 to 0.464. I take 0.4 as the mean, which cannot be far from the truth. The number of stars of each magnitude after the first are, according to Dr. Ball, second mag-

nitude, 65; third magnitude, 190; fourth magnitude, 425; fifth magnitude, 1100; sixth magnitude, 3200; seventh magnitude, 13,000; eighth magnitude, 40,000, and ninth magnitude, 142,000. Now, dividing the stars into sets which ought to give equal light on the hypothesis of uniformity, we can easily ascertain to what magnitudes the stars in each set belong; and multiplying the number of stars of any magnitude by the figure which represents the intensity of light for that magnitude, we obtain a result which shows in what direction the deviation from uniformity takes place. Thus the second set consists of 140 stars which will embrace the whole 65 second-magnitude stars, together with 75 stars of the third magnitude. If the average light of a star of the first magnitude is represented by 1, that of a second-magnitude star will be represented by 0.4, and of a third-magnitude star by 0.16. Hence the actual light of this second set will be represented by $65 \times 0.4 + 75 \times 0.16$ or 38, whereas on the hypothesis of uniformity the value of the total light ought to be 20. There is, therefore, in this instance a very marked deviation in the direction of excess.

Carrying on this computation I found that several successive sets will, in many instances, consist altogether of stars of the same magnitude. As the number of stars in each set is greater than in any preceding set, there would in such cases appear to be a continual increase in the light if, in each case, I multiplied the number in the set by the average intensity for that magnitude. But the smaller sets contain the brighter, and the larger sets the fainter stars of any given magnitude, and the apparent increase has therefore, in all probability, no foundation in fact. I have therefore thought it best to strike a general average for all such sets, without attempting to trace whether the total light increases or diminishes as we pass from the earlier to the later. This plan, however, is not available when a set includes stars of two different magnitudes; and it is evident that if it includes only a few of the fainter stars of one magnitude while it contains a large number of the brighter stars of the following magnitude, its total light will be underrated on the principle of averages. When this state of things is reversed the light will in like manner be overrated. I have applied the principle of averages throughout for want of a better, but I desire to state that the sudden increase of light at the tenth set, and the equally sudden diminution at the fifteenth

set, appear to be due to the causes which I have mentioned, and that I have no reason for believing that these sets present any abnormal characteristics. With this preface I give the following Table as the result of my computations:—

				Total light.
1st set,	20 stars of the first magnitude	.	.	= 20
2nd set,	65 2nd magnitude + 75 3rd magnitude	.	.	= 38
3rd set,	115 3rd magnitude + 265 4th magnitude	.	.	= 35.4
4th set,	160 4th magnitude + 580 5th magnitude	.	.	= 25.1
5th set,	520 5th magnitude + 700 6th magnitude	.	.	= 20.5
6th set,	1820 6th magnitude	.	.	= 18.6
7th set,	680 6th magnitude + 1860 7th magnitude	.	.	= 14.6
8th set,	3380 7th magnitude	.	.	} = 15.8
9th set,	4340 7th magnitude	.	.	
10th set,	3420 7th magnitude + 2000 8th magnitude	.	.	= 17.3
11th set,	6620 8th magnitude	.	.	} = 14.3
12th set,	7940 8th magnitude	.	.	
13th set,	9380 8th magnitude	.	.	
14th set,	10940 8th magnitude	.	.	
15th set,	3420 8th magnitude + 9500 9th magnitude	.	.	= 11.3
16th set,	14420 9th magnitude	.	.	} = 12.9
17th set,	16340 9th magnitude	.	.	
18th set,	18380 9th magnitude	.	.	
19th set,	20540 9th magnitude	.	.	
20th set,	22820 9th magnitude	.	.	
21st set,	25220 9th magnitude	.	.	

In this Table the second and third sets are largely in excess of what they ought to be on the assumption of uniformity, and the excess is partly carried on to the fourth set; from whence it would appear that the stars of the second, third, and fourth magnitudes are much more numerous, comparatively speaking, than those of the first. We seem to be in fact traversing a comparatively barren region surrounded by regions much richer than itself—regions which our remote ancestors may have traversed, and which our remote descendants may traverse—regions I may add which may have left their impress behind them in those vestiges of the past which it is the province of the geologist to trace. But still more remarkable is the steady decline of the total light from the second set down to the twenty-first, beyond which my data did not suffer me to proceed. I have already given my reasons for not regarding the tenth and sixteenth sets as exceptions to this law, and the apparent deviation at the eighth set seems to admit of a similar explanation. Few astronomers will, I think, be of opinion that

a steady thinning-out of the star-system sets in as early as the average distance of a star of the fourth magnitude; but I do not see on what other principle the results embraced in the foregoing Table can be explained unless it be the absorption of light by some interstellar medium. In the case of a star of the ninth magnitude I cannot estimate this absorption at less than one-third of its total light—probably more. At all events the aspect of star-distribution on which I have dwelt deserves more attention than it has hitherto received; and now that photographic measures of the intensity of the light of stars are being superadded to the photometric measures previously employed, more numerous and reliable results may ere long be expected.

There are two other modes of regarding the problem which I may briefly notice. The first is:—We have seen that on the hypothesis of uniformity the 20 inner stars whose average light is 1 are succeeded by a set of 140 stars whose average light is $\frac{1}{7}$; these by a third set of 380 whose average light is $\frac{1}{19}$, and so on. Now, instead of dividing the stars into successive sets of 20, 140, 380, &c., in order of brilliancy, and ascertaining whether their total light exceeds or falls short of the constant quantity supposed by our hypothesis, we may divide them into successive sets whose average light is 1, $\frac{1}{7}$, $\frac{1}{19}$, &c., and examine whether the number of stars in each set exceeds or falls short of that given by the theory. I endeavoured to apply this method, and the results were rather singular. The first set of course contains the 20 first-magnitude stars as before, but the second set, instead of containing 140, was found to contain no less than 508. After such a figure a deficiency in the succeeding set was perhaps to be expected. At all events it appeared, for the set only contained 245 stars while theory gave 380. But when I came to the fourth set I found that it vanished altogether. Its average light is $\frac{1}{37}$; but the third set, constructed on the present principle, terminated among the fifth magnitude stars, whose average brightness is between $\frac{1}{39}$ and $\frac{1}{40}$. It thus appeared as if all the stars whose light averaged $\frac{1}{37}$ were required to balance the brighter stars of the third set, and bring down the average of that set to $\frac{1}{19}$. Probably, however, the complete vanishing of the fourth set was illusory. The set commences in the first hundred of the 1100 stars of the fifth magnitude, and there can be little doubt that the brilliancy at this stage exceeds $\frac{1}{37}$.

But though the set does not vanish, it must contain a much smaller number of stars than the 740 afforded by the theory—probably not half that number. After such a check in the arithmetical computation as this, I did not think it necessary to proceed any farther. The result, however, strikingly confirms my former conclusion as to the great richness of the region of stars immediately beyond that through which we are travelling.

The third mode of looking at the problem would be much the most satisfactory if we possessed the requisite data for applying it, but unfortunately we do not, nor are we likely to do so for a very long period. This method would consist in taking the 20 nearest stars as our first set; the 140 nearest to them as our second set; the 380 next in point of nearness as the third set, and so on; and then to compare the light of the several sets as thus determined. But to go no farther than the first set, what astronomer would venture to specify the 20 stars that are nearest to us? While, however, we thus lack the requisite data, we can see in a general way the kind of effect that would be produced by substituting the nearest for the brightest stars in arranging our successive sets. The light of the first set would be reduced. Several stars of the first magnitude would be excluded from it, and their places taken by stars of much inferior brightness, such as 6 and 61 Cygni. In fact the leading 20 would probably include four or five stars of a magnitude not superior to the sixth. Probably the light of the second set would also be reduced, but not to the same extent. Several stars of the second and third magnitude would, no doubt, be excluded from it, and their places taken by fainter stars. But as a set-off we should find included in it several first-magnitude stars among them, perhaps such giants as Canopus, Wega, and Arcturus. The relative preponderance of the second set over the first would thus be increased. Somewhat similar observations will apply to the subsequent sets. Each would contain many stars of inferior magnitudes to those assumed in my Table, but they would also contain many stars of superior magnitudes; and probably by the time that we reached the tenth or twelfth set, the brighter and fainter stars thus introduced would balance each other, and the average brightness would be sensibly the same as in the Table. If further researches should show that the steady decline in the total light of each set continues below the point where this equivalence may be supposed

to exist, the evidence in favour of an absorptive medium will be proportionally strengthened.

In conclusion, I am well aware that the data on which I have proceeded are not sufficiently reliable to warrant very positive conclusions on the subject, though I think the Table which I have constructed exhibits in at least two respects—the great rise after the first set, and the subsequent steady decline—features which can hardly be ascribed to insufficient or erroneous observations. I am likewise aware that I have only attacked one branch of the question of star-distribution—the distances of the star-masses as distinct from their directions. But notwithstanding this, I believe that the views which I have put forward are in some respects new, and that they possess a basis of truth; which will, I trust, be a sufficient apology for laying them before a meeting like the present.

LXIV. — NOTE ON THE SPECIFIC HEAT OF THE ETHER.

By GEORGE FRANCIS FITZGERALD, M.A., F.R.S.,
F.T.C.D. ; Erasmus Smith's Professor of Natural and
Experimental Philosophy in the University of Dublin.

[Read, May 18, 1885.]

It is not quite accurate to describe the quality of the ether that is here called its specific heat by that name. The energy of the ether per unit volume is not in exactly the same form as heat-energy in matter. It is in the form of vibrations transmitted continually through it, and is more nearly analogous to sound vibrations in matter. As this energy of the ether is, however, intimately connected with the temperature of the matter that is in it; and as its amount depends on that temperature, it is quite intelligible to speak of the temperature of a volume of ether, meaning that it is on all sides in temperature equilibrium with surrounding matter: on these accounts it is intelligible, and, with proper restrictions as to its meaning, quite right to speak of the specific heat of the ether. There is no danger of the words being mistaken as referring to anything else than what they are intended to describe. It must, however, be clearly kept in view that the energy per unit volume of the ether is not exactly like that of matter. We can also only calculate the energy per unit volume, for we don't know whether any perfectly intelligible meaning can be attached to the mass of the ether.

The problem to be solved in determining the specific heat of the ether is, What is the increase in the quantity of energy per unit volume of the ether that corresponds to its temperature being raised one degree? If we consider the temperature equilibrium of a surface of lampblack, which is assumed to be approximately a perfect absorber and radiator when it is one degree hotter than its surroundings, it is seen that it is radiating energy outwards at a certain rate, and receiving it at a certain less rate. Now, the energy per cubic centimeter of the ether considered as transmitting radiations outwards is greater than its energy considered as transmitting radiations inwards, and it is this difference that causes the

transference of energy at a certain rate away from the lampblack. If we could calculate the whole energy of either of these radiations, it would tell us the whole energy per cubic centimeter of the ether considered as a medium transmitting radiations in a particular direction, and six times this amount would evidently be the total heat per cubic centimeter of the ether at this temperature. This very calculation has been performed approximately for the solar radiations, where we can approximately measure the total radiation in a particular direction; but as we only know very roughly, indeed, what is the temperature of the surface of the sun, we can only calculate very roughly what is the total heat of the ether per cubic centimeter at that temperature. As in addition we don't know the laws of cooling for any sufficiently large range to apply it safely to the sun, we could only very roughly, indeed, calculate the total heat of the ether per cubic centimeter at temperatures with which we are in the habit of dealing. We can, however, from experiments on the rate of cooling of lampblack, calculate pretty accurately the difference between the energy per cubic centimeter of the ether at slightly different temperatures, and this tells us the specific heat of the ether at this temperature. If $\frac{dq}{dt}$ be the quantity of heat per second lost by each square centimeter of surface of lampblack when its temperature is 1°C. hotter than its surroundings at the temperature of 0°C. , then this energy is distributed over V cubic centimeters of ether where V is the velocity of light in centimeters, and consequently $\frac{dq}{dt} = \frac{cV}{6}$ is the equation by which to calculate c , the specific heat of the ether. The 6 comes in owing to this being the energy required to raise the temperature of the ether by radiations going in only one direction. From several sources which, however, only approximately agree with one another, I gather that $\frac{dq}{dt} = .0026$. The great difficulty in determining this is to distinguish between the heat carried off by the gas present, and that lost by radiation alone. As $V = 3 \times 10^{10}$, we see that $c = 5.2 \times 10^{-13}$. Of course, as was to be anticipated, this is a very small quantity, and is very small even compared with the specific heat per cubic centimeter of the gas in a good vacuum. The specific heat per cubic centimeter of an air vacuum of one millionth of an

atmosphere, such as we can probably attain, is about 7×10^{-10} , so that the energy required to heat up such a vacuum would be practically all used in heating the matter present, only the one thousandth part being required to increase the vibrations of the ether present.

If we apply Dulong and Petit's law to calculate the specific heat of the ether at different temperatures, we obtain the following results:—We have obtained the equation that

$$\frac{dq}{dt} = \frac{cV}{6}$$

expresses the relation connecting $\frac{dq}{dt}$, the rate of cooling with c , the specific heat of the ether.

Now, according to Dulong and Petit's law,

$$q = k(a^t - a^{t_0}),$$

where q is the quantity of heat per second lost by radiation, when one body is at t and its surroundings at t_0 . He also calculated that for all bodies $a = 1.0077$. As I am assuming the theory of exchanges, I may as well at once assume that the total quantity of heat lost per second is

$$Q = ka^t,$$

and that there is

$$Q_0 = ka^{t_0}$$

radiated in the opposite direction, so that what I have called the total heat of the ether is

$$H = \frac{6ka^t}{V}.$$

To calculate c we can use the result I have just used, and say

$$\frac{dq}{dt} = \frac{cV}{6} = ka^t \cdot \log_e a,$$

and we thus get

$$k = .35;$$

so that, approximately, $Q = .35 \times (1.0077)^t$. From this we can calculate the total heat per cubic centimeter of the ether at different temperatures, and get

$$H = 7 \times 10^{-11} \times (1.0077)^t,$$

and the specific heat per cubic centimeter

$$c = 5.2 \times 10^{-13} \times (1.0077)^t.$$

Even at the estimated temperature of the sun at 3000°C . this would be still only

$$c = 5.2 \times 10^{-3};$$

but it is evident that if the specific heat of the matter in a gas is at all nearly constant up to these temperatures, a very large part of the heat energy would be in the ether if the gas were rare. This is what one would expect in considering temperatures of spark discharges, and accounts for their very short duration.

It is quite easy to apply the same considerations to calculate these quantities upon other laws of cooling, but this whole subject is so uncertain it is hardly worth doing more than point out what is to be done.

LXV.—ON SOME METHODS OF MEASURING THE DENSITIES
OF GASES. BY GEORGE FRANCIS FITZGERALD,
M.A., F.R.S., &c.

[Read, June 15, 1885.]

THE following methods depend on determining the amount by which a body is buoyed up when immersed in the gas.

The first arrangement consists of a large thin glass ball sealed up and suspended by a bifilar suspension. The period of oscillation of such a ball round a vertical axis depends on the distance apart of the suspending fibres, on its moment of inertia, and on the weight of the ball. This latter depends on the density of the gas in which it is immersed, and by observing the time of oscillation of the ball it is possible to determine the density of the gas. In order to do this conveniently it is well to make observations of the period of oscillation in two gases of known densities, as for instance in air at the ordinary atmospheric pressure, and at a very much lower pressure obtained by exhausting by an air pump the vessel in which the ball is suspended. As the relation connecting the number of oscillations per second (N) of the ball with the density (δ) of the gas in which it is immersed is of the form

$$N^2 = A + B\delta,$$

two observations serve to determine A and B , and then any other density can be determined in terms of N , the number of oscillations performed by the ball. From experiments I made I believe it is easy to arrange that the ball shall perform one hundred oscillations without their amplitude being either initially too large or finally too small; and if by making the length of the suspending threads long (this is better than making their distance apart small, as this latter introduces a correction depending on their torsion), the period of oscillation be considerable, it is evidently possible to determine this period very accurately. It is better to determine the period of this oscillation round a vertical axis than its period of oscillation as a pendulum, because, without a very long suspension, this latter would be more rapid, and would besides be more damped

by the gas present. If, however, means were employed for keeping up the oscillations, as, for instance, by attaching a small piece of iron to the ball, and attracting it when in the middle of its swing by means of a magnet, or by moving the point of suspension, or by other means, the period of oscillation could be determined to any desired degree of accuracy. The complete theory of the experiment is, however, very complicated. The highest mathematics have been expended on calculating the effect of the gas present on the period of oscillation of a pendulum; and although the theory of a sphere performing oscillations round one of its diameters is enormously simpler, yet the way in which its period of oscillations depends on the viscosity of the gas is rather complicated, and this would make it a rather complicated operation to calculate accurately the density of the gas from observations with this instrument. It might, however, be used for rough observations, and as the same series of observations by giving the logarithmic decrement of the amplitudes of oscillations would give a measure of the viscosity of the gas, it would be an interesting instrument to make observations with on a considerable series of gases and vapours.

The second instrument I constructed works upon the same principle as an old philosophical instrument called a "Baroscope". It was constructed for the purpose of demonstrating the amount by which bodies are buoyed up by the air in which they are immersed. A piece of cork or a glass bulb is balanced in a rough balance by a lead weight. If this be placed under the receiver of an air-pump, the lead weight no longer balanced the cork or bulb, as it is no longer assisted by the presence of dense air. A delicate apparatus of this kind is evidently capable of exactly the same accuracy as the ordinary method of weighing the gas in the bulb, as in Dumas' method, for it is only weighing the gas displaced by the bulb instead of that in it. As, however, most delicate balances are large, I thought it might be well to construct an apparatus of this kind on a very small scale, so as to be able to deal with comparatively small volumes of a gas. I have, therefore, constructed one as follows:—I blew a thin glass bulb of about 1 cm. diameter on a fine quill tube which I drew out to a thinner stem about 2 cm. long. To the end of this I attached a mirror such as is used for galvanometers with its plane at right angles to the stem. At a point in the stem close to the bulb I attached two very small and

sharp splinters of glass which projected away from the stem in such a way that the whole thing could be supported on the two sharp points of the glass splinters. By bending the stem judiciously, and attaching small pieces of glass to regulate the balance, it is comparatively easy to arrange that the whole thing shall balance on these two sharp points, and perform slow oscillations, proving that its centre of gravity is close below the line joining these points. The mirror should be vertical, and the stem nearly horizontal. If it be now supported by the two points resting in the concave side of a splinter of a fine glass tube, the whole apparatus can bear to be moved about freely without shaking off its supports. If it be now placed so as to reflect a spot of light from the mirror to a vertical scale, or if an image of a vertical scale in its mirror be viewed through a telescope, it is possible to observe the position of the instrument very accurately. If the density of the air in which the apparatus is immersed be changed its position of equilibrium alters, and the spot of light is reflected to a different point of the scale. I have constructed an instrument of this kind, in which the alterations of position on a scale about one meter off are as great as the alterations of the mercury barometer gauge of the air-pump, showing that it is possible to determine pressures with this instrument nearly as accurately as with a mercury barometer gauge. This is of course the same as determining the density of the air, for it is the density and not the pressure of the gas present that affects the position of the instrument. I have found that the most satisfactory way of using the instrument is to have some means, as by an attached sprengle or other air-pump by which to alter the pressure of the gas in which the instrument is immersed, until the spot of light or image of the scale is in some standard position, such as it takes up in air at a known temperature and pressure. Under these circumstances the density of the gas is the same as that of this air, and an observation of the temperature and pressure of the gas enables its density at any other temperature and pressure to be calculated. As the whole thing can be put inside a tube four centimeters long, and three in diameter, it could evidently be easily jacketted so as to keep it at a high temperature, and then be used to measure the densities of vapours, the only precaution required being that the temperature should be sufficiently high to prevent the gas from condensing as

a liquid on the apparatus. A small correction might also be required for the expansion of the glass by heat. As the whole thing can be made of glass, for even the mirror need not be silvered, it is applicable to such corrosive gases as chlorine, bromine, and iodine.

It is evident that a large number of applications of the same general principle are possible: as, for instance, by weighing a bulb immersed in a vapour, as in Mr. Joly's calorimeter, in an ordinary balance, or by using spring balances to determine the weight of the bulb. A very pretty one might be made by an application of Messrs. Ayrton and Perry's shaving springs, and it might be made very delicate by reading the position of the bulb by reflection from a mirror attached to it. By suspending a thin balloon of collodion, distended by a heavy gas in a gas, the density of the latter might be measured with a very delicate balance that would not bear the weight of a glass bulb.

LXVI.—ON THE COLOURING MATTERS EMPLOYED IN THE
ILLUMINATIONS OF THE “BOOK OF KELLS.” By
W. N. HARTLEY, F.R.S., Royal College of Science,
Dublin.

[Read, June 15, 1885.]

No one who has visited the Library of Trinity College, and had the privilege of examining the “Book of Kells” can fail to have been impressed with the beauty, quaintness, and intricacy of the designs, and the brilliancy of the colours of the illuminated letters and embellishments. Owing to the unsatisfactory character of some of our modern water-colours and oil paints, I have been asked to give an opinion upon the nature of the colours which have remained permanent after a period of possibly 1200 years. For obvious reasons the pigments in question could not be submitted to any process of chemical manipulation; hence conjecture, judgment, and comparison were exercised in deciding upon an answer. As any information concerning this interesting and beautiful relic of ancient Irish art may possibly be acceptable to the Royal Dublin Society, I beg that this may be accepted as an apology for presenting so unimportant a scientific contribution. It is my desire to state at the outset that this question was put to me by Mrs. D’Olier, whose very beautiful reproductions of the designs in the “Book of Kells” have been executed with such loving care as to excite the admiration of all who carefully examine them. Mrs. D’Olier has rendered me a very remarkable amount of assistance in some cases by giving me a true description of the pigments, and to her my best thanks are due. Accepting the earliest supposed date of the manuscript as being of the seventh century, it is necessary to restrict our ideas of the colours that could be used to those known at, or prior to, this time. A very careful examination of the work shows that the pigments mixed with gum, glue, or gelatine are laid on somewhat thickly—there is no staining of the vellum and no mingling of tints. There is, however, as was pointed out to me a painting of blue over a ground of green. The colours, which are not very numerous, consist of a black, a tint resembling burnt

sienna, a bright red, a yellow (largely used), a neutral green, an emerald green, two blues, a lilac, and a reddish purple. The yellow is much employed in filling up finely-traced designs. The black of course is lampblack, or possibly fish-bone black, that is to say, charred fish-bones, or some other form of carbon artificially prepared, in a finely-divided state. The reds, the yellow, the greens, and the blues could be obtained either—first, by grinding natural mineral substances; second, by grinding artificially coloured enamels or glasses. The very appearance of the colours is in favour of the first rather than the second, and altogether against a third, possible process of preparation, namely, by the formation of those substances known as lakes which are precipitates of vegetable or animal pigments in combination with alumina or lime. By making comparisons with ground minerals, I conclude that the bright red is realgar (arsenic disulphide, As_2S_2); the yellow is orpiment, auripigmentum, the gold colour of the ancients (arsenic tersulphide, As_2S_3); and the emerald green is malachite, an ore of copper (basic carbonate of copper, $\text{Cu}_2\text{CO}_3 \cdot \text{CuH}_2\text{O}_2$). The deep blue might be lapis-lazuli, the natural ultramarine, but I am inclined to think not, for the following reason: where the green is enhanced in beauty by an overlying coat of blue, the effect is that of a transparent pigment, such as could not be produced by lapis-lazuli. The reddish purple, I am of opinion, is either a finely ground glass coloured with gold, or a preparation similar to that known as the purple of Cassius. Its very sparing use must not be overlooked, and may be justly regarded as an evidence of its costly nature. It is not alone that it is employed in a few places, but it is put upon the vellum in very thin washes.

I have sought for information concerning the colours used by the ancients, for the reds and yellows recalled to mind the colours of Egyptian and Assyrian decorative paintings. There are three or four works which deal with this subject: Sir Humphrey Davy's Paper in the *Philosophical Transactions* of the Royal Society for 1814, on colours employed by the painters who executed the frescoes on the walls of the Baths of Titus and the houses of Pompeii; Dr. Thomas Thomson's *History of Chemistry*, vol. i., p. 77, published in 1830; and a recently published Paper by M. Berthelot, "Sur les Notations Alchimiques," in the *Annales de Chimie et de Physique*, 6th series, vol. iv., p. 370; also a work by the same author,

of great value and remarkable interest which has just been published, *Les Origines de l'Alchimie*. The information given by Dr. Thomas Thomson is derived from the writings of Pliny, Vitruvius, and Dioscorides, he likewise quotes from Sir Humphrey Davy's Paper. M. Berthelot quotes largely from manuscripts and papyri preserved in the National Library at Paris, the Greek manuscript in the Library at St. Mark's, Venice, and the papyrus in the Museum at Leyden. According to Thomson, Pliny describes two kinds of colours, namely, the florid and the austere. The names of the florid colours were, minium, armenium, cinnabaris, chrysocolla, purpurissimum, and indicum purpurissimum. The austere colours were of two kinds, the native and the artificial. The native were known as sinopis, rubrica, parætonium, melinum, eretria, auripigmentum. The artificial were, ochra, cerussa usta, sandaracha, sandyx, syricum, and atramentum. The Greek manuscript from the Library of St. Mark is the earliest work on alchemy extant; it dates from the tenth or eleventh century, but the information it contains is derived from much earlier Egyptian sources. In describing the colours mentioned above, it will be convenient to quote occasionally from Thomson's work, and to give the original Greek names which appear in the fac-simile representations of pages of the manuscripts quoted in M. Berthelot's work.

Placing the NATURAL COLOURS first, we have the following:—

Reds.

Cinnabar. *Κινναβαρίς* (St. Mark MS.), *Κινναβαρεί* (Leyden MS.), mercury sulphide, the most abundant ore of mercury. It was called minium; and red lead, an artificial colour, was also known by the same name. The modern pigment vermillion should correspond to this.

Armenium, a yellow ochre or orange colour. Sinopis. *Σινωπική*, also *Σινωπὶς ποντική* (St. Mark MS.), a red substance now known as Venetian red, or raddle. It is used for sheep-marking, and in parts of England for reddening the brick floors of cottages. It was procured from Pontus in the Balearic Isles, and it was doubtless an iron ore with more or less combined water.

Ochre. *Ὠχρά* (St. Mark MS.). "Ochre is merely sinopis heated in a covered vessel." "Rubrica, from the name, was pro-

bably a red ochre." Substances now known as ochres consist of highly ferruginous clays.

Sandaracha. *Σανδαράκη* or *Σανδαράχη* (St. Mark MS.). This was realgar, the red arsenic disulphide, $\text{As}_2 \text{S}_2$. Both this substance and ochre were found in the island of Topazos in the Red Sea.

Yellows.

All pigments of this colour examined by Davy proved to be iron ochres, sometimes mixed with a little red lead. "Orpiment was undoubtedly employed, as is obvious from what Pliny said on the subject." Davy found in one instance massicot, or lead protoxide, mixed with some red lead.

Misy. *Μίσυ* (St. Mark MS.) was a yellow copperas.

Greens.

Chrysocolla. *Χρυσόκολλα* (Leyden MS.). This was a green-coloured paint, and, from Pliny's description of it, could have been nothing else but the basic carbonate of copper, now known as malachite. All green paints examined by Davy were carbonates of copper. The mineral chrysocolla is a blue silicate of copper, $\text{CuSiO}_3 \cdot 2\text{H}_2\text{O}$.

ARTIFICIAL COLOURS.

Reds.

Cerussa usta and minium both signify red lead; this is an artificial colour made by roasting lead.

"Sandyx was made by torrefying equal parts of true sandaracha and sinopis," that is to say, by heating a mixture of realgar and ochre.

Siricum. *Σιρικόν* (St. Mark MS.). This was made by mixing sinopis with sandyx.

Blues.

The blue pigment *κυανόν* (St. Mark MS.) is made by preparing a frit or glass made from wood ashes, or alkali, sand, and copper ore. It is very largely employed in the different apartments of the Baths of Titus. Different shades of colour were obtained by an admixture of body colour, most usually chalk. This pigment is quite unaltered by exposure to the air and sun.

Indicum purpurissimum—"From the statement of Pliny that, when thrown upon hot coals, it gives out a beautiful purple flame, this was obviously indigo."

Purples.

Purpurissimum was a high-priced pigment, made by putting a kind of white clay into caldrons containing the ingredients for dying purple: it was therefore a lake. The celebrated purple dye of the Tyrians was obtained from a shell-fish, the murex or buccinum. Davy ascertained that the colouring matter of the ancient purple examined by him was combustible; the probability is very great that it was a preparation of this character. Berthelot says, however, that the ancients were undoubtedly aware that glass could be coloured purple by means of gold, and that they appear to have been not unacquainted with the purple of Cassius, which is obtained from a solution of gold by the action of a solution of tin. According to our knowledge of this substance, it appears to have been discovered by Cassius of Leyden in the year 1683, for the earliest description of its preparation we owe to him. In *Les Origines de l'Alchimie*, p. 93, it is remarked that there appears to have been an intimate connexion between the preparation of metallic compounds and the process of dying purple. This is suggestive of the probability that gold was used for the purpose.

From the work attributed to Democritus, it is evident that several purple colours were in use, namely, cochineal; archil, obtained from lichens; garancine, from the madder root; and likewise indigo. The lilac tint in the "Book of Kells" was probably a lake prepared from lichens. See *Les Origines de l'Alchimie*, pp. 350-361.

As to the source of supply of these colours, one cannot otherwise suppose than that, in the early days of the Christian era, and still further back, the art of preparing colours was inseparable from the art of painting, for even at the present day there are English painters who can prepare their own colours, vehicles and varnishes, and whose processes have been handed down to them by their masters. The master who taught the art of designing and painting to the artist who executed the "Book of Kells" unquestionably knew how to prepare the colours. As for the materials, malachite, $\text{CuCO}_3 \cdot \text{CuH}_2\text{O}_2$, green in colour, is found near Cork and Limerick; chrysocolla, $\text{CuSiO}_3 \cdot 2\text{H}_2\text{O}$, green to blue in colour, is found in the county Cork;

chrome, hæmatite, and ochres occur in the county Wicklow; of red hæmatite of an earthy nature, such as is termed raddle, there is a plentiful supply in the county Antrim. Orpiment and realgar must have been obtained from elsewhere, and the purples were undoubtedly of artificial origin; it is probable they were brought from abroad, and such colours were no doubt treasured as jewels.

LXVII.—ON AN ABNORMAL SOLAR SPOT. BY WENT-
WORTH ERCK, LL.D.

[Read, June 15, 1885.]

For the last three weeks the disturbance of the photosphere has been confined to the southern hemisphere, chiefly between the parallels of 12° and 15° . It has manifested itself in the production of large, isolated spots, and not, as frequently, in numerous small ones.

The northern hemisphere has been perfectly free from disturbance.

On the 9th June a very great spot was observed in lat. 15° S., and 35° E. of central meridian. The umbra, or nucleus, of this spot was very much elongated in the direction parallel to the solar equator.

June 10, 675.—The disturbance on this parallel was evidently increasing; the single elongated umbra had then resolved itself into two, entirely distinct, but both enveloped in a common penumbra.

This is not an unusual occurrence; but the mode in which it took place was most remarkable. Each of the component umbræ was roughly pear-shaped, the small ends pointing toward each other. The penumbra was continuous round the two umbræ, but much constricted at the place of their separation.

The general appearance strongly suggested an oblong mass of viscous material, stretched till torn asunder by external forces applied at each end, the penumbra maintaining a constant breadth from the edge of the umbra outwards, and therefore being constricted where the breadth of the umbra vanished.

The appearance presented was utterly inconsistent with the idea of an internal disruptive or explosive force, and seemed absolutely to require the operation of pulling forces applied at each end; or of two powerful currents converging from the following side on the centre of the original spot. Next day the penumbra also had divided itself at the point of constriction, and there appeared two ordinary spots, completely separated from each other by a central interval of seven helio centric degrees, or about 35,000 miles.

The existence of powerful southerly currents was inferred from the manner in which the umbræ of both—but specially of the preceding spot—was invaded by bridges of photosphere, entering from the southern side, and which promised rapidly to disintegrate the entire spot. It is important to ascertain whether either of these spots occupied the position of the original. The longitude of the original was fortunately observed on the 9th, previous to the disruption.

Again, on the 11th, after disruption, the longitude of the largest of the two separated spots was taken; again on the 13th, and again on the 15th. The daily amount of rotation during the first interval, between the 9th and 11th, was $12^{\circ} \cdot 5$; that during the second interval, between the 11th and 13th, $12^{\circ} \cdot 80$; that during the third interval, between the 13th and 15th, $12^{\circ} \cdot 81$; while the average movement due to latitude 15° , according to Carrington, is $13^{\circ} \cdot 1$.

The differences, between the quantities are less than the possible errors of observation, and therefore we seem justified in assuming that the position of the spot observed was the same as that of the original spot, and that the separation of the spots was wholly due to the motion of the smaller, or the preceding, of the two.

It is to be remarked that the difference of longitude of the two spots had increased from 7° on the 11th, to 12° on the 15th; and as the primary spot appears to have retained its original longitude unaltered, the secondary spot must have been endued with a proper motion in longitude of its own, the motion being in that direction which would shorten the rotation period, and so approximate to the rotation period of the equator.

I would ask have we here any analogy to the state of affairs disclosed by the Jovian atmosphere, in which the red and the white spots, having nearly the same latitude, give different periods of rotation, and are therefore endowed with a proper motion of their own, as though different spherical envelopes of the atmosphere were rotating in different periods?

Position of original spot, lat. 15° S., and it crossed the central meridian, June 12, 7.75, G. M. T.

LXVIII.—FURTHER REMARKS ON STAR-DISTRIBUTION.

By W. H. S. MONCK.

[Read, June 15, 1885.]

IN a Paper, read before this Society (*antea*, p. 470), I assumed that, although the brightness of an individual star is no test of its distance from us, the average distance of the stars of any given magnitude is less than that of the stars of the next succeeding magnitude. As this assumption did not appear to meet with universal acceptance, I desire, on the present occasion, to state some reasons in its favour. I need hardly say that the very faintest of fixed stars would appear brighter than Sirius, if it approached us sufficiently, while Sirius itself might be removed to such a distance as to become invisible to our most powerful telescopes. Reasons more definite than this will, however, be expected from me, and these I proceed to give.

Assuming that there is no medium in space which absorbs light, the general expression for the brightness of a star will be $\frac{l \cdot s}{d^2}$, where l represents the illuminating power of each unit of surface, and s the area of the illuminated surface. If there is an absorbing medium, the expression will, of course, be somewhat different; but into this I shall not at present enter. Now, if we compare a considerable number of instances taken at random, in which the value of $\frac{l \cdot s}{d^2}$ is high, with a considerable number, likewise taken at random, in which the same value is much lower, is it reasonable to suppose that the difference depends wholly on the factors l and s , and that the average value of d is either unaltered or increases when the average value of the fraction diminishes? I think not. But we are able to take another step. There is probably no instance in which we are able to ascertain the value of s or the extent of illuminated surface which the star turns towards us; but we can form a very fair estimate of the value of l , and are thus enabled to conclude positively that several of the stars of the first

magnitude do not owe their position in the stellar scale to the intense illumination of the unit of surface. When a cold body is gradually heated it gives forth at first dark heat, and then a red light, after which the other hues in the solar spectrum gradually spring up, and finally the ultra-violet chemical rays make their appearance. At every stage in this heating process the illuminating power of the unit of surface increases; and the illuminating power of the unit of surface can thus be determined within certain limits by the nature of the stellar spectrum, being lowest in the case of the red stars, and highest in that of the brilliant white or blueish stars—at least, unless the latter owe their peculiar hue to the loss of the red rays, which fact would always be revealed by the spectrum. We are in this manner able to conclude that the degree of illumination of several stars of the first magnitude is not above, but below, the average. Such stars, for instance, are Aldebaran, Antares and Arcturus. If these are really distant stars, the extent of illuminated surface must be enormous. From their lower temperature these stars are probably in a more condensed condition than the brilliant white or blueish stars already alluded to, and the masses which we would have to assign to them, if they were very remote stars, would be almost incredible. Before leaving this subject, I may remark that our early astronomers, at least in the northern hemisphere, appear to me to have framed their nomenclature with a view to the colour of the stars. If we examine the stars of the first magnitude visible in this country in alphabetical order, we shall find ourselves passing at almost every stage from a redder to a whiter or bluer star—the few departures from which rule may perhaps be explained by a change of colour since the names were imposed. Thus, Capella, which stands pretty high in the alphabetical list, is described by many of the earlier writers as a red or reddish star.

However, it is said that, though much labour has been expended in trying to ascertain the parallaxes of stars of the first magnitude, very few of them present a sensible parallax, while several of the fainter stars do so, and also that many faint stars exhibit a larger proper motion than the stars of the first magnitude. This reasoning would be conclusive against a theory which supposed that the distance of a star was invariably indicated by its magnitude; but I think it has little force against one which only supposes that the

average distance of the stars of any given magnitude is greater than the average distance of the stars of the magnitude next above it. Nearness and remoteness in the case of the fixed stars must be determined on a different scale from that which we employ in dealing with the solar system. The nearest of them is much more remote than Neptune; but it is not improbable that there are stars within the range of our telescopes whose distance exceeds that of α Centauri more than a thousandfold. Any star whose distance does not exceed ten times that of α Centauri must be regarded as a near star. On the hypothesis of uniformity there would be one thousand such stars, and the actual number is as likely to exceed one thousand as to fall short of it. But, taking the annual parallax of α Centauri at $\frac{9}{10}$ of a second, the annual parallax of a star ten times as distant would be only $\frac{9}{100}$ of a second; and I think it will be admitted that such a parallax could not be measured by our present methods and with our present instruments with any approach to accuracy. That we have tried to find a parallax for any given star and have failed is therefore no proof that it is not a near star. In fact, the number of stars which are universally admitted to have a sensible parallax might almost be counted on one's fingers. But, to revert to the parallax of stars of the first magnitude, I turn again to Dr. Ball's *Elements of Astronomy*, which contains a valuable collection of facts which are quite sufficient for my present purpose. Beside α Centauri I find a very fair concurrence by different observers in the case of Sirius, the parallax of which can hardly be less than $\frac{1}{5}$ of a second. Two measures only are given of the parallax of Arcturus, but they agree in fixing it at between $\frac{1}{7}$ and $\frac{1}{8}$ of a second. The more recent determinations of the parallax of Vega are also in fair agreement, and give a result larger than in the case of Arcturus, and perhaps equal to Sirius. There is therefore, I think, good reason to conclude that four stars of the first magnitude possess a sensible parallax; and, judging from Dr. Ball's figures, there are at least four more with regard to which further investigation may not improbably lead to the same conclusion, though the present data are either too insufficient or too discordant to afford any positive result. These are β Centauri, Al Tair, Capella and Procyon. If I am right in these conclusions, 20 per cent. of the stars of the first magnitude have a sensible parallax, and further research may not improbably increase this

number to 40 per cent. Now, is there the smallest probability that a similar per centage of the stars of any other magnitude will be found to possess a sensible parallax? I think not. When fainter stars have been examined for parallax they have been almost always selected for large proper motion, or some other supposed indication of nearness, and were not therefore fair specimens of their class. But what do we find even as regards these selected stars? Of four hundred and nine, examined by Dr. Ball at Dun-sink, two only gave a sensible parallax. Granted that a parallax, equal to that of Sirius or Wega, might have escaped observation on the methods employed by Dr. Ball, still the fact that only $\frac{1}{2}$ per cent. of the specially selected stars turned out to have a sensible parallax is, I think, rather a startling one. No doubt astronomers were at first a little surprised at finding that several stars of the sixth magnitude have a sensible parallax; but, as the stars of that magnitude are one hundred and sixty times as numerous as those of the first magnitude, it would require one hundred and sixty stars with sensible parallaxes to compensate for α Centauri alone. There seems to be no chance of detecting one-fourth of that number. The evidence afforded by researches on parallax hitherto is therefore, I think, entirely in favour of the smaller average distance of the brighter stars. Individual faint stars are sometimes nearer than individual bright ones; but this does not affect the question when we are dealing with averages.

From parallax I pass to proper motion. I think there is no doubt that the great proper motion of some faint stars is mainly due to the fact that the actual velocity of their motions is very great. Grounds might, perhaps, be alleged for holding that the average velocity of small stars is greater than that of large ones; but, at all events, there is no more reason to believe that all stars are moving with the same velocity than that all stars are equally bright at the unit of distance. The test of proper motion, however, has a defect from which that of brightness is free. Besides the distance of the star and the velocity of its motion; the direction of the motion must also be taken into consideration, for, if the star is moving towards us or away from us, the proper motion will appear insignificant, although the distance may not be great, and the actual velocity of motion may be considerable. However, the evidence of proper motion is, I think, likewise favourable to the

smaller average distance of the brighter stars. In M. Flammarion's Introduction to his *Star Atlas* I find a table of sixty stars having the greatest proper motion observed up to that period, arranged in order of magnitude; and, comparing these with the total number of stars of each magnitude as given by Dr. Ball, I ascertained what per centage of the stars of each magnitude fell into this selected batch of sixty. The result is as follows:—

	Per Cent.		Per Cent.
1st Magnitude,	20·	6th Magnitude,	0·41
2nd Magnitude,	1·54	7th Magnitude,	0·11
3rd Magnitude,	1·58	8th Magnitude,	0·02
4th Magnitude,	1·17	9th Magnitude,	0·003
5th Magnitude,	0·63	All others,	·0

Here, again, no doubt, the proper motions of the stars of the first magnitude have been examined more carefully than those of the fainter stars; and, in the case of some of the latter, even since the publication of M. Flammarion's Table, large proper motions have been discovered. But I think it very unlikely that the stars of the first magnitude will be displaced from the position which they occupy; for, the last of the four which are included in M. Flammarion's list—Procyon—is the thirty-eighth in the Table; and it will therefore be necessary to discover twenty-two fainter stars with larger proper motions to exclude him from the leading sixty. But even if we lost both Sirius and Procyon, the two stars which there is no chance of displacing— α Centauri and Arcturus—would secure the first place for the stars of the first magnitude, which would still contribute ten per cent. of their total number to the list in question.

I proceed to mention some other indications of comparative nearness, which, so far as I am aware, are almost exclusively confined to the brighter stars—that is, to the stars of, say, the first four magnitudes. One of these consists of two well-separated stars, one of which nevertheless revolves round the other in a moderate period. Such a star, for instance, is ξ in the Great Bear, where the two stars can be easily separated, while the period of revolution is only about sixty years. Sirius is in the same position, though his companion is so faint that a powerful telescope is necessary, not to separate the stars, but to detect the smaller one. We

cannot suppose such double stars to be very distant from us without ascribing an almost incredible velocity to the revolving star. It is otherwise, of course, when the double star is a very close one, or when the period of revolution is very long. But, I believe that duplicity of any kind occurs more frequently in the case of the brighter than of the fainter stars, and that the average distance of the pairs is also greater in the former case than in the latter. This is exactly what we should expect to find if the brighter stars were nearer. In speaking of double stars, I exclude cases in which the two stars are not known to have any physical connexion, and, though nearly in the same direction, may be at very different distances from us. Excluding these stars, I believe the feature on which I am insisting will be much more frequently found among the brighter than the fainter stars, though I am unable to give any statistics as to the proportion.

My next reason is founded on what I may call star-systems—stars fairly separated from each other, yet moving in nearly the same direction and with nearly the same velocity. Such, for instance, is the case with five of the seven stars which form the Plough, or Charles's Wain, in the Great Bear. They are all bright stars, but probably further examination will show that some faint stars in the same direction are also members of the system. Now, considering the great angular distances of these stars from each other, their mutual action would be almost inconceivable if they were not near stars in the sense in which I have been using that phrase. I think I may go a step farther. This system appears to be sweeping through space uninfluenced by the action of the numerous fainter stars which we see around it; for if it once got entangled in a mass of stars moving in different directions and with different velocities, it is difficult to see how the common motion of the system could be preserved. The natural inference therefore is, that these faint stars are much more distant from us than this system of five—that, great as the mutual distances of the members of that system must be on the lowest computation, the distance of the system from the general mass of the stars in the Great Bear is still greater. A somewhat similar system exists in Cassiopeia's Chair, embracing most of the brighter stars in that region. The angular distance of its members is less than in the Great Bear, but the component stars are also less brilliant—the

two indications of greater distance thus concurring. Still, if the motions of this system are independent of those of the great mass of the stars in Cassiopeia's Chair, as they appear to be, this mass of faint stars must be much more remote than the brighter stars which form the system. This result is the more remarkable because the fainter stars are unusually dense in this region.

Further evidence on the same subject is afforded by clusters of stars. Of course if any cluster was brought nearer to us the component stars would appear to widen out, and though for some time the density of the cluster might be preserved by the springing up within it of faint stars, which were invisible at the greater distance, if it still continued to approach us, a pretty wide separation of the component stars would ultimately be effected. Now it is, I believe, a fact that in every cluster where the component stars are tolerably bright, as in the case of the Pleiades and the Hyades, a wide separation is effected by the telescope, while in all very dense clusters the component stars are extremely faint. Our densest clusters in fact are not visible to the naked eye at all, and in inferior telescopes they appear only as *nebulæ*. It seems difficult to explain the inverse relation between the density of the clusters and the brightness of the component stars on any other hypothesis than that the average nearness of any group of stars increases with their average brightness.

I may likewise allude to the general distribution of bright and faint stars over the sky. If brightness did not depend on distance, we might expect to find the same proportion existing everywhere, or at all events to find this proportion as variable in one direction as in another—to find, for instance, that if the density of the faint stars increased more rapidly than that of the bright stars in one rich region, another rich region would be found in which this state of things was reversed. This, however, does not appear to be the case. When we pass from a poorer to a richer region I believe the brighter stars are never found to increase as rapidly as the fainter. Their arrangement seems to indicate that they are moving at a comparatively short distance from us, while the great mass of the faint stars lie far beyond them. There is no instance, I believe, in which a really bright star is known to belong to a cluster or to a system, the other components of which are much inferior to it in brilliancy. Except in the case of the faint companions of a

bright double or multiple star, the brighter stars seem to keep aloof from their inferiors, and when they form systems they keep these systems to themselves.

I may further remark that the principle that faintness is a mark of great distance has been acted on by astronomers in their researches after parallax, and in several instances it has been verified by the results thus obtained. This was the mode in which Bessel first determined the parallax of 61 Cygni. Suspecting from its large proper motion that this star was near us, he selected two fainter stars in the neighbourhood, which he assumed to be so remote that for practical purposes their distances might be regarded as infinite. The same operation was repeated by Struve on another faint star in the neighbourhood, and the near coincidence of their results seems to prove that the stars thus selected are really much more remote than 61 Cygni. Struve's star was fainter than either of Bessel's, and the slight discrepancy in their results would be explained by supposing that it was also more distant. The same method has subsequently been adopted by other observers. Had the stars which Bessel and Struve selected for reference been much brighter than 61 Cygni, their results might not have met with such universal acceptance. Possibly, too, these results would have been different.

On these grounds, I am inclined to think that there is a sufficient average correspondence between the magnitude of a star and its distance to justify the conclusions which I draw from that assumption as approximations to the truth. Of course it is only when we are dealing with wide averages that such results are of any value, and therefore their value increases with each successive magnitude, provided that we have sufficient data to work upon. When we take in a wide region of space, distributed impartially in every longitude and latitude, it seems probable that the peculiarities of different portions of this region will compensate each other, and that the general average, computed on the hypothesis of uniformity, will not be far from the truth. I already noticed that as the twenty brightest stars are certainly not the twenty nearest stars, the average distance of a first magnitude star is almost certainly greater than it would be on the hypothesis of uniformity. But this is only partly true of the stars of succeeding magnitudes. All subsequent magnitudes will indeed contain stars which owe

their position, not to their distance, but to their great brilliancy at the unit of distance, but they will also contain stars whose distance is less than the average, but whose want of absolute brilliancy has prevented them from figuring in a higher class. How far we should have to go before this kind of compensation would become perfect it is not easy to determine, but at all events we would approach nearer to the theoretic value at every stage—the average increase of distance being below the theoretic value during the earlier stages of the process. This theoretic value is easily computed if we assume that no light is absorbed in passing from the stars to us. The average light of the stars of any magnitude being taken as $\frac{2}{5}$ of that of the stars of the preceding magnitude, the average distance will be found by multiplying the average distance of the stars of the preceding magnitude by $\frac{1}{2}\sqrt{10}$ or 1.58 nearly. This value of $\frac{2}{5}$, I may add, is closely approached by the recent computations of M. Littrow and Mr. Pogson, as well as being very nearly the mean of Dr. Ball's authorities. This theoretic value of 1.58, however, is liable to be reduced at the earlier stages of the process by the cause which I have mentioned, while if there is in a space a widely-diffused medium which absorbs light it would also be affected by the absorption, especially at the later stages. To what extent this would affect the theoretic value would depend on the law of absorption.

It occurred to me since my former Paper that the effects of this supposed absorptive medium might be revealed in a somewhat different way. On the hypothesis of uniformity the entire number of stars up to any given magnitude would be included in a sphere having the earth as its centre. The total light of all these stars would be proportional to the radius of this sphere, while the total number of the stars in question would be proportional of the cube of the radius (assuming that no light was lost in the passage). We would thus have two modes of calculating the proportion which the radius of any of these spheres bore to the radius of any preceding sphere, viz. :—1st., by computing the total light in each case (which could be easily done when we know the number of stars of each magnitude and their proportionate brilliancy); and 2nd, by finding the total number of stars comprised in each sphere, and comparing the values of the cube roots of these numbers. If there was no absorption, and the averages derived from the hypo-

thesis of uniformity were approximately true, we should arrive at the same result by both modes of computation ; but if light is absorbed by the medium, the value derived from the total light should always be less than that derived from the total number of stars. I accordingly tried this method on the stars from the first to the ninth magnitude inclusive, taking the numbers of the stars from Dr. Ball's Table, and computing the total light on the assumption that the average light was represented by the multiplier $\frac{2}{3}$ at each stage of the descent. The first pair of figures shows a wide divergence in the opposite direction from that which would be produced by the absorption of light, which I attribute to the great richness of the region of the second magnitude stars, our field not being yet wide enough to render the uniformity-hypothesis approximately true. At the next step the divergence is in the same direction, but much reduced ; at the third stage the figures are practically equal ; and in the remaining five the figure derived from the number of stars is considerably in excess of that derived from the total quantity of light, both figures displaying a good deal of steadiness, as appears by the following Table :—

Sphere.	Multiplier derived from number of stars.	Multiplier derived from total light.
1st to 2nd,	1.62	2.30
2nd to 3rd,	1.48	1.66
3rd to 4th,	1.37	1.36
4th to 5th,	1.37	1.27
5th to 6th,	1.41	1.25
6th to 7th,	1.53	1.32
7th to 8th,	1.48	1.30
8th to 9th,	1.51	1.33

The divergence in one direction, at the earlier stages, does not compensate for the opposite divergence at the later ones. The multiplier which represents the total change from the first to the

ninth sphere, as computed from the number of stars, is 21.54, while that computed from the total light is only 18.82. This would seem to indicate a loss of at least $12\frac{1}{2}$ per cent. of the total light of all the stars up to and including those of the ninth magnitude, which of course implies a much greater loss in the case of an average ninth magnitude star; and if I had made the computation between the second and ninth spheres instead of the first and ninth, the loss would appear to be over 35 per cent.

As our knowledge of the ether increases, I think the chances of its proving a light-absorbing medium are becoming greater, on purely physical grounds, and apart from astronomical data. We know of no other medium which transmits vibrations without absorbing some of them. The ether is an active agent in the production of electric and magnetic phenomena, and thereby, no doubt, assists in the production of light and heat otherwise than by transmission. Independently too of the supposed evidence of Encke's comet, there are magnetic phenomena in which the ether, when in a particular condition, appears to be capable of resisting the motion of ponderable matter. There seems, moreover, to be some reason for thinking that all bodies in the universe (except a small number, which are temporarily heated by collision or some similar cause) are perpetually cooling; and if so, what becomes of the heat unless it is absorbed by the ether? However, I shall not pursue this subject farther.

The absorption or non-absorption of light will of course make a considerable difference in our estimates of the distances of very faint stars. From the foregoing figures it would seem that the average distance of a star in the ninth sphere is about twenty-one and a-half times that of a star in the first sphere. The ninth sphere, however, includes not merely the stars of the ninth magnitude, but those of all magnitudes higher than the ninth, so that the average distance of a ninth magnitude star will be greater than this. It cannot, however, be very much greater, because 71 per cent. of the total number of stars included in the ninth sphere are stars of the ninth magnitude. If we assume it to be twenty-six times as great as that of a first magnitude star, we shall probably have made a sufficient allowance. On the hypothesis of uniformity, however, and not allowing for any absorption, the ratio would be $(\frac{1}{2}\sqrt{10})^8$ to one, or very nearly thirty-nine times as great. I have already

given a reason for thinking this figure too high, but the two results could evidently be reconciled by a large absorption. On that view the loss of light would be so considerable that a star should be placed at twenty-six times the distance of a first magnitude star, in order that the light which reached us should be that due to thirty-nine times the distance, none being supposed to be lost. The absorption would thus amount to $\frac{5}{9}$ of the total light. Probably the absorption is not so large as this, but if we halved the difference between the two results the loss would still amount to at least 36 per cent. If there is an absorption therefore a faint star will always be nearer to us than we would infer from the intensity of its light, on the hypothesis of uniformity. How much nearer will of course depend on the amount of the absorption.

LXIX.—ON THE OCCURRENCE OF BERYL WITH SCHORL
IN GLENCULLEN VALLEY. BY PROFESSOR J. P.
O'REILLY.

[Read, June 15, 1885.]

IN the mineral collections existing in Dublin may be found specimens of beryls, from various places in the neighbourhood of Dublin where granite occurs. Samples from Dalkey Quarries, from the Three-Rock Mountain, from places in Wicklow, such as Glenmalure and Glenmacannus, have been mentioned. The specimens now shown were found in quarries, known locally as the Kearneystown Quarries, situated in the Glencullen Valley, near Glencullen Bridge, on the south side of the stream. These quarries are opened in granite, and have been worked for some time, so that the excavations are extensive, and show a considerable front of rock. The distance from the stream is about eighty to one hundred yards, and in the principal quarry there exists a joint or fissure which, so far as I could judge, is parallel to the course of the stream, presenting a direction about N. $62^{\circ} 40'$ W. (being the same as that of the group of jointings which I described as occurring frequently in the environs of Dublin with a mean direction of N. $60^{\circ} 41'$ W.). This joint is filled in certain parts of the quarry with what is called "rotten stuff" by the quarrymen, that is, granite much broken and decomposed, and presenting in several places along its direction, bunches of schörl, large crystals of orthoclase and muscovite mica, these assuming a somewhat plumose arrangement. At one particular point a rock was detached, which contained not only these minerals but also well-marked crystals of beryl. The quarrymen threw it aside, and broke off some of the stuff. The large bunch I secured, and it is now in the gallery of the Royal College of Science. The small hand samples now exhibited show the crystals with some well-marked forms of the prism and basal section; at the same time it is clear that the interior of the crystals is not homogeneous, and has undergone a certain amount of decomposition. It is evident that these crystals were

formed prior to the schörl, as they are completely enclosed by this mineral, the crystals of which are flattened on the faces of the beryls. In other places the beryl is completely decomposed, and has resulted in a clay of a light-green colour and unctuous feel, which may be remarked in many other granites of the county Dublin, but which we may thus presume to have resulted from the decomposition of beryls. It will be of interest to determine whether these clays contain any glucina, or whether, in the process of decomposition, all the glucina is carried off in a soluble state. It will also be interesting to determine whether the green earths, here and there noticeable in the Dalkey granites, are really to be accepted as resulting from the decomposition of beryls, or to be considered as independent minerals.

There is a further point in connexion with this occurrence of beryl worth noticing. It is the evidence it furnishes as to the depth and extent of the main jointing affecting the granite masses of the county Dublin, and the probability that it points to some of these joints developing into lodes at their contact with the mica slates, which in this particular case are not far distant.

Lastly, I look upon the existence of this well-marked jointing as an evidence that Glencullen Valley is a fissure valley, which is quite in keeping with its markedly rectalineal direction.

LXX.—NOTE ON THE OCCURRENCE OF GRANITE PORPHYRY IN THE THREE-ROCK MOUNTAIN, COUNTY DUBLIN. BY PROFESSOR J. P. O'REILLY.

[Read, June 15, 1885.]

THE mass of granite which has received the name of the Three-Rock Mountain, though apparently of very simple outline, presents in certain places channels and gorges which become recognizable from a distance towards sunset when the rays of the sun, passing at a very low angle, bring out the inequalities of the surface very markedly. It may thus be seen that certain shallow gorges and channels occur, and that their directions are apparently parallel. One of these is known to the quarrymen of the village of Sandyford and environs as "Phuldhu," and in the southern end of it I found last year a block of granite, partly detached from the mountain, the texture of which struck me as interesting by reason of the great development of the orthose crystals. I had the blocks separated from the main mass, and saw-cut and polished in the part where these crystals appear. The slab resulting, now exhibited, presents a very agreeable colour, owing to the size and structure of the flesh-coloured orthose crystals. I had already noticed the directions of these gorges, and included this one in the group of jointings, having the mean direction N. $6^{\circ} 57'$ W. I, therefore, assume that the porphyritic character points to the presence of one of these joints in the gorge, along which the same character may be found to present itself in other places. Were the rock thus characterized more abundant, it might give rise to an adaptation for ornamental purposes; but I am not aware of it occurring with this appearance in any other locality of the mountain.

LXXI.—NOTE ON AN ABNORMAL DEVELOPMENT OF *PICEA* PINSAPO. BY GREENWOOD PIM, M. A.

[Read, June 15, 1885.]

PASSING through Powerscourt demesne, a week or two ago, my attention was arrested by a curious growth, on a rather large specimen of *Picea pinsapo*, of which I submit a photograph. A large side branch had divided into two, each of which was about $1\frac{1}{2}$ inches in diameter. Of these one grew in the usual horizontal manner, while near its origin the other developed into a gouty swelling, from which the normal branch was not much more than half an inch thick. At right angles to this, and from the swelling, arose the growth which caught my eye, a dense bush of short rather slender shoots, of a pale yellow green, quite different from the usual colour of the young growth in this species, and so thick as to be quite impenetrable to vision, somewhat reminding one of the "nests" of a birch tree. It contrasted in colour much more than appears in the photograph. Further examination showed several other instances of a similar growth on this tree, but none so large or perfect as this one, which was about 2 ft. high by 1 thick. The tree is a very fine one, about 30 ft. in height, and the trunk at the base about 15 inches in diameter.

LXXII.—ARTIFICIALLY-PRODUCED GOLD CRYSTALS. BY
WILLIAM N. ALLEN.

[Read, December, 15, 1884.]

GOLD crystals are occasionally found native; the occurrence, however, of the crystalline metal in the laboratory has, as far as I can find, not yet been published.

The crystals which are microscopic were deposited by a neutral solution of chloride of gold and sodium, and appear as regular three- or six-sided tables perfectly crystalline in structure; the forms are those of octahedra, the largest observed being $\frac{3}{1000}$ inch in diameter.

Many present surface-markings, of which I exhibit a good example; there is considerable difficulty in obtaining definition, owing to the great surface reflection.

With a very oblique light, it can be observed that the edges present a bevelling, the reflection being such as would be given by crystals having the forms figured in *Muspratt's Chemistry*, vol. ii., p. 265.

The only note I find which refers to gold separating in laminæ from solution has been kindly given me by Mr. R. J. Moss, F.C.S. It is from a work by M. Golfier Bessayer, *Annales de Chimie et de Physique*, published in 1832, in which it is stated that a solution of gold chloride, prepared with as little acid as possible, and which was laid aside for some time, then contained a quantity of small and very brilliant spangles (*pailletes*) of gold, the author apparently did not recognize them as *crystals*.

The word "spangle" is used by Fresenius in his *Qualitative Analysis*, 8th ed., p. 144; but the spangles of gold obtained as directed by him do not present crystalline structure.

In connexion with this subject, I exhibit copper crystals deposited in a mixture of cupric sulphate, treacle and vinegar; the forms are similar to those of the gold crystals, and to those of copper, which occur in the well-known "Aventurine glass."

LXXIII.—NOTES ON SOME IRISH FISHES. BY J. DOUGLAS
OGILBY, Senior Assistant-Zoologist, Australian Museum, Sydney.

[Read, June 15, 1885.]

THE recent publication of Dr. Francis Day's important work on the *Fishes of Great Britain and Ireland* has led me to a close examination of the Irish species and localities mentioned, and as my notes have extended to a considerable length, I now offer them as a contribution towards a revision of the Irish Fishes, upon which my friend Mr. A. G. More and myself have been for some time engaged.

Labrax lupus.¹—In addition to the example mentioned (Day, p. 10) as having been recorded from Portrush, county of Antrim—which, if mine from *Zoologist*, 1876, p. 4754, should by rights be from Portstewart, county of Derry—I have since obtained a magnificent specimen, scaling $13\frac{3}{4}$ lbs., caught in my presence with a seine on the west strand, Portrush, Oct. 8, 1878. The stomach contained numbers of Paguri, and two young coal-fish, each about five inches in length. Shortly after this date I was informed of the capture of another specimen, weighing over 10 lbs., by a boy engaged in fishing for flukes with a lug-worm bait, a short distance inside the mouth of the Bann. On the 17th July, 1883, I saw a bass of about 6 lbs. weight, which had been taken in the Foyle, opposite St. Johnston, and about thirty miles above the mouth of the river. Although the man who had it stated that he had seen one previously, it was so little known that he called it a “big herring.” From these observations it would appear that the bass only visits our northern coasts in the autumn, as a straggler of large size and solitary. In the Belfast market they begin to appear about the middle of June, from the nets set in the Lough.

Polyprion cernium.—The only specimen of which I have heard is that recorded by Andrews (*Nat. Hist. Rev.*, vol. ii. p. 38), as having been caught off Ventry, Dingle Bay, during September, 1854; weight, $10\frac{1}{2}$ lbs; length, $25\frac{1}{2}$ inches; and is probably the same as that mentioned by Dr. Day.

¹ The Latin names are taken from Dr. Day's Work.

Mullus barbatus.—Is said to occur, but very rarely, in the Belfast market. I have failed to obtain an example.

Pagellus centrodontus.—Abundant at Portrush, where it is called “brazier”. Fished for with hand-lines from a boat anchored at the edge of a tide or in eddies, the first two hours of the flood being the best time for this fishery, and the baits employed being crab, or boiled limpets. Also taken commonly on “spotty ground”, *i. e.* patches of rock and shell-sand, upon lines set in a slack tide, and baited with mackerel, garfish, or sand-eel, with a mixture of whelk. I have known a single example to have taken an india-rubber eel while whiffing for pollock.

Cantharus lineatus.—Rutty was evidently mistaken in his identification of this species, which has not been since taken in the localities mentioned, though his record would lead one to suppose that it was not uncommon. I never saw one either at Kingstown, Dalkey, or Killiney, in all which places I have frequently fished. In botanical matters also, as well as in his account of the Mammals of Dublin, little reliance can be placed on Rutty’s accuracy.

Sebastes norvegicus.—There seems to be an error in the first Irish record given by Dr. Day, p. 44; the notice in the *Dublin Nat. Hist. Proc.* runs somewhat as follows:—“Two fine specimens taken in the month of March last, on the long lines set for ling in deep water off the Wild Bank, Dingle Bay.” The Paper was read on May 4, 1849, in above *Proc.*, vol. ii. p. 61.

[*Cottus gobio*.—There seems to be no doubt that this species does not exist in any of our northern rivers.]

Cottus scorpius.—Both this, and the next species, *C. bubalis*, are called “Johnnie Doran” (never, that I have heard, “miller’s thumb,” as stated in the foot-notes to pp. 80, 81, of Thompson) on the coast about Portrush, and “cobbler” at Bray, where both are common, the latter, however, being the more numerous of the two.

Trigla cuculus.—Next to the grey gurnard, this is the most abundant species about Portrush, its proportionate numbers with *T. hirundo* being about three to one (*vide* Thompson, p. 73, *contra*). It is probable that Thompson was led astray in his computation, because of this fish being kept mostly for home use, while its larger congener is sent to market.

Trigla hirundo.—I have on several occasions taken this fish

whilst whiffing for mackerel, but generally when putting the boat about, and in water not exceeding five fathoms ; when thus hooked they play fiercely. I have, however, observed individuals not unfrequently on the surface above a considerable depth, and once unsuccessfully pursued an example, which had captured a fluke too large to be swallowed with ease. The largest example which I have ever taken measured exactly two feet, and weighed $5\frac{1}{2}$ lbs.; this was in July, and the fish in perfect condition. I cannot imagine one of 14 lbs.; surely there is some mistake or slip of the pen?

Agonus cataphractus.—I have never known of a specimen being caught by trawlers or shrimpers on the Derry coast. My only example was taken from the stomach of a cod, caught about six miles from land, in twenty-five fathoms.

Lophius piscatorius.—Locally called "Brahwin," and not uncommon. The largest example which I obtained measured 5 feet 7 inches, and contained a ling of 8 lbs. weight, in so fresh a condition that it passed muster when thrown out on the quay without exciting suspicion in the mind of the purchaser. The colours of this fish—the only individual I have ever seen caught on a hook—when first taken out of the water were most beautiful, the upper parts being of a deep-rich purple, shading on the sides through mauve into the white of the belly; within half an hour, however, these tints faded away, leaving behind only the ordinary dirty brown and white livery in which they generally come under the observation of naturalists. There was no sign of breeding in this specimen, which was caught during the month of January, 1877, in thirty fathoms, mixed bottom. They are generally washed ashore in a dead or dying condition, and are not used as food on the north coast, being looked upon with great disgust by the fishermen, who invariably kill them and throw them overboard.

[*Trachinus draco*.—In Miss Cusack's *History of Kerry*, p. 443, Dingle Bay is given as a habitat of this fish. This is no doubt a repetition of Andrews' record in *Dublin Nat. Hist. Proc.*, vol. i. p. 122; Paper read 1854. The list of Kerry fishes was contributed by him, but no specimens were ever sent to Dublin.]

Trachinus vipera.—In the *Zoologist* for Jan., 1876, I mentioned the fact that this species will rise to a small white fly, from per-

sonal experience, not from hearsay, as the text, p. 82, would lead one to believe; but in all the cases in which I caught them thus, the sun had been some time set, so that it was difficult at a glance to distinguish between this and the young coalfish for which I was angling. It is known at Portrush by the suggestive name of "brute." On our coast the usual remedy applied to cure its wound is to prick the puncture until it bleeds freely, and while the blood is flowing immerse the affected part in spirits of turpentine or whiskey. I have been pricked several times, but I never felt any inconvenience, so much depends on the state of health of the sufferer. So numerous are they sometimes that I took thirty-five, one of which was $6\frac{3}{4}$ inches long, during two hours' shrimping by night, in the ladies' bathing-place, Portrush.

Scomber scomber.—Common at Portrush, from July to September inclusive. Owing probably to some local cause, they appear earlier and in larger numbers at Ballintoy to the eastward, and Magilligan to the westward. Numbers of small mackerel were taken on the Donegal and Dublin coast during December, 1882. I have never previously remarked them at that season. Young fry, up to 4 inches long, are caught at Portrush in August.

[*Scomber colias*.—In the *Dublin Nat. Hist. Soc. Proc.*, vol. ii. p. 106, Andrews records one sent to him, but without stating from whence it came. In Miss Cusack's *Kerry* he gives the locality as "off Tearaght Island, county of Kerry," but the fish does not seem to have been satisfactorily identified].

Orcynus thynnus.—In the record of this species, p. 97, two distinct occurrences seem to have been confused together. Three Irish examples are now authenticated as follows:—(1) Dr. Jacob's, caught off Dublin Bay about the year 1828, and measuring about 2 feet; (2) William Thompson's, which came ashore living, in Ballyholme Bay, near Bangor, county of Down, in the autumn of 1841; it measured 8 feet 3 inches long, 5 feet 4 inches in girth, and weighed fully 300 lbs.; (3) my own, hitherto unrecorded. This example was obtained at Portrush on the 1st September, 1878: its total length was 8 feet; girth 5 feet 1 inch; length of head to total length as 1 to 4; weight computed at as between 3 and 4 cwts. Its stomach contained a number of mackerel in different stages of digestion, and about a quart of thick brownish-red fluid matter. We had been for some time aware of the presence of

several large fish in the bay, from seeing them shoot along the surface in pursuit of the shoals of mackerel, glassan, and lythe, and after the capture of this example others presumably of the same species were observed, so that it is probable that a small shoal of tunnies had visited us, attracted no doubt by the abundant supplies of food obtainable, for which that year was especially remarkable. The individual in question was, it is supposed, frightened by an incoming steamer, and passing through the harbour mouth, traversed its entire length, and stranded with such impetus as to jamb itself between the dock-wall and a sunken lighter, where it was easily despatched. It was carried about from village to village as a show, until it became a nuisance, and was finally buried. [One taken off Dingle in December, 1883, is in the Dublin Museum of Science and Art.—A. G. M.]

Thynnus pelamys.—Referring to the specimen preserved in the Andersonian Institute, and obtained from the neighbourhood of the estuary of the Clyde, Dr. Scouler is careful to state that it “could not be mistaken for *Pelamys sarda* (*vide* Thompson, *Nat. Hist. Ireland*, vol. iv. p. 95); and I cannot see any reason for doubting his correctness. Yarrell’s 33-inches example, of which I see no notice in the 3rd edition, can hardly have been the Cork (Bennett’s Court) fish, which is distinctly stated to have been 29½ inches long, 21 inches in girth, and 19½ lbs. weight. The specimen from Wexford has long ago perished, but Mr. More informs me that one taken near Clifden, county Galway, in the autumn of 1883, is in the Science and Art Museum.

Centrolophus pompilus.—In Miss Cusack’s *Kerry*, Andrews records this fish as found in Brandon Bay, Dingle Harbour, and off the Skelligs. The only example of which I have any knowledge was forwarded by the late Mr. W. Andrews to the Museum of Science and Art, Dublin, where it is now preserved in spirit; it had previously been salted by a fisherman, and is referred by Mr. More, the curator of that Museum, to the above species.

Brama raii.—In the month of July, 1878, an example of this rare fish was washed ashore dead, but in a perfectly fresh condition, on the east strand, Portrush, after a severe north-westerly gale. Though the person who picked it up would not part with it, he kindly allowed me to make such an examination of it (comparing it with Yarrell’s and Günther’s descriptions) as sufficed to

thoroughly satisfy me of its identity. The length was 15 inches, and the dorsal and caudal fins were considerably injured. I was subsequently informed by its finder that it was "very good eating". I may mention in this connexion that Thompson does not state that this fish specially is called "hen-fish" in Ireland, and that Tramore is the name of the locality whence Dr. Burkitt received his specimen. M'Skimmin was undoubtedly wrong in his identification.

Schedophilus medusophagus.—During the second week of August, 1878, I obtained a fine specimen of this fish, the first recorded from the British seas, which was taken in a salmon net, at Portrush, and measured $9\frac{1}{2}$ inches. For further particulars see Dr. Günther's account in the *Trans. Zool. Soc.*, vol. xi. part VIII., p. 223, 1882.

Lampris luna.—The fish taken in the Foyle during July—not June—1835, was *Zeus faber*, as stated in the "Ordnance Survey of the parish of Templemore, county of Derry;" and as shown by the fin rays given, D. 9 (spinous), p. 13 (vide infra, *Z. faber*). The example of June, 1849, cannot be said to have been taken "in Derry," having been caught at Innistrahull, off the Donegal coast.

Caranx trachurus.—Called "rock herring" at Portrush, where it is very irregular in its visits. During eight years' acquaintance with that coast, it occurred but once, in the autumn of 1878, when vast shoals appeared following the herring fry, which on many occasions were driven ashore in such numbers that they were lying heaped up in masses several inches deep at the edge of the tide while their pursuers were caught in small seines by actual cart-loads, and hawked about the neighbourhood at almost nominal prices. So plentiful and fearless were they that I caught, within an hour, eight dozen scad and mackerel with my hands, while wading in water up to my knees.

Naucrates ductor.—Crookhaven (in Cork) is the name of the place where the only Irish example was obtained.

Capros aper.—The first announcement made by Andrews of the capture of this fish occurs in the *Dublin Nat. Hist. Soc. Proc.*, vol. ii., p. 104, and was read April 9, 1858, when the capture was probably recent. This example was "taken in a trawl off Ventry harbour." There are two specimens, both presented by Mr. Andrews, in the Dublin Museum of Science and Art, but they are not dated. In Miss Cusack's *Kerry*, p. 443, Andrews gives

"Dingle Bay," but does not mention how many specimens were obtained, nor date of capture; and as Ventry harbour opens into Dingle Bay, this is probably the old record reproduced in a different form. Such carelessness is very reprehensible, and materially increases the difficulty of obtaining reliable records in all branches of Irish natural history.

Zeus faber.—Dorees are by no means common about Portrush, where such as are obtained are chiefly taken by the trawlers. They are of small size, about 2 lbs. being the average, and 4 lbs. the largest I have ever seen there. In the ordinance survey of Templemore (v. *supra*, *Lampris luna*) this fish is mentioned as having been taken on the 9th July, 1835. All the species included in this report are stated to have been captured "in or above the salmon nets at Culmore," some twenty miles above the mouth of the Foyle.

Sciaena aquila.—The single Irish specimen was caught opposite the town of Passage, which is above Queenstown, Cork, and quite six miles from the entrance to the harbour. (This mistake probably arose from the omission of the capital letter in Thompson's *Nat. Hist. of Ireland*, vol. iv., p. 90.)

Trichiurus lepturus.—Mr. More tells me that the first Irish specimen was recorded by the late Dr. A. Leith Adams from Kinsale, county of Cork, in the *Field* for January 28, 1871. In the *Dublin Nat. Hist. Proc.*, vol. vi., p. 68, Andrews also gives the date as January, 1871; and in Miss Cusack's *Kerry* the record is given, "five specimens obtained in Brandon and Tralee Bays (Dr. Bustead)."

[*Obs.*—*Lepidopus caudatus*.—Ball, in the *Nat. Hist. Review*, vol. ii., p. 45, gives it as a "probable occurrence": only a head was examined. Couch mentions, no doubt, the same example. For the present it can scarcely be included in the Irish list.]

Gobius ruthensparri.—Thompson (p. 116) records the example taken from the stomach of a tern. It is remarkable that I never obtained a goby of any species at Portrush.

Gobius niger.—Mr. More is of opinion that Thompson's Tory Island specimens belong to this form, not to *G. paganellus*, to which latter all the other localities are to be assigned.

Callionymus lyra.—I have taken the male at Bray, county of Wicklow (where they are called "sandfish"), on a line set for

flukes, and baited with lug-worm, in five fathoms of water. The females are sometimes common in Portrush harbour during summer and autumn; but I never caught a male there. They are somewhat uncertain in their appearance, being numerous in some seasons and scarce in others. (Achill Island.—A. G. M.)

Cyclopterus lumpus.—Adult examples are occasionally taken in the salmon nets at Portrush during April and May, but they are never common. During the summer and autumn months I have, however, frequently taken the young, of from half an inch to an inch in length, adhering to crab-creels and tangle.

[*Liparis vulgaris*.—We do not think that this species has any claim to a place in the Irish list.]

Anarrhichas lupus.—The records of this fish as Irish are not very satisfactory. Templeton only mentions having seen them in Belfast market, and merely conjectures that they may have been caught in the Bay. I never saw or heard of one in the Portrush market. Dr. Jacob's record is possibly correct, as may be also Dr. Ball's; but in no case is it positively proved where the examples were captured. There has not been any native specimen in the National Museum within Mr. More's recollection, that alluded to by Thompson having disappeared.

Blennius gallerita.—Dr. Day has transferred the Irish localities of this species to *Carelophus ascanii* (see below), a fish which Mr. More has not personally taken. The announcement of the discovery of Montagu's blenny on the Irish coast runs thus: "Several at Dingle harbour, 1868; coast of, and islands off, Connemara, 1869." (A. G. More, in *Zoologist*, 1878, p. 297.)

Blennius pholis.—It is not necessary that the water should flow at every flood into the rock-pools frequented by the shanny, since I know many haunts, which only receive an accession of sea water during stormy weather or exceptionally high spring-tides. This species is more numerous and of larger size in shallow pools along the rocky shore to the north of Inver, Donegal Bay, than I have met with it elsewhere.

Carelophus ascanii.—Since noticing the above species in the *Zoologist* for January, 1876, I obtained so many examples from crab-creels during the warm months of that and the two following years, that I consider it quite as numerous as *Blennius gattorugine*, with which it is usually found associated. They are only taken

in fairly deep water where the bottom is rocky and weedy. All those over five inches had lost the transverse bars, which I therefore take to be a sign of immaturity. The Dalkey and Newcastle fishes—Yarrell's Wicklow (Dublin), and Down records—though possibly correct, rest on insufficient authority. Transfer More's records to *B. galerita*. See under that species.

Centronotus gunnellus.—As local names, it is called "nine-eyes" at Portrush; "nanny nine-eyes" at Bray; and, according to Thompson, "clavin" and "flutterick" in the north; "coddick" at Carrickfergus (J. Doo); and "lamprey" at Roundstone (*fide* M'Alla).

[*Obs.*—*Zoarces viviparus*.—Templeton's record is insufficient; and we are, therefore, of opinion that this fish should be omitted from the Irish list: and indeed it is one of those eastern species which need hardly be expected on our shores.]

Cepola rubescens.—Dr. Farran's specimen was obtained at Stradbally, county of Waterford. It is exceedingly doubtful whether the report of its abundance in that locality is correct, resting as it does on the unsupported testimony of fishermen alone. (Often found in the stomach of turbot; also taken off Howth and in Dublin Bay.—A. G. M.)

Trachypterus arcticus.—Mr. William Darragh, of the Belfast Museum, kindly writes me, under date Dec. 14, 1883, that the Donegal example, when received, was in so advanced a state of decomposition, as to be unfit for preservation. (See *Zoologist*, 1875, p. 4343).

Atherina presbyter.—Small examples—two to three inches long—when split longitudinally into four pieces form an irresistible bait for pollock, glassan, and all other fishes, which can be caught by whiffing.

[*Obs.*—*Mugil capito*.—In addition to Dr. Harvey's statement in the *Fauna of Cork*, Professor M'Coy (*Ann. Nat. Hist.*, vol. vi., p. 403) records this species from Dublin Bay. Requires proof.

Mugil chelo.—All the mullets—many scores—which I have examined from the coast-line between Lough Foyle and Belfast belonged to this form. Mr. More's experience of specimens from the shores of Dublin, Cork, and Kerry is similar.

Gasterosteus aculeatus.—I have examined numbers of these little fishes from many northern localities, varying in elevation

from drains opening into the sea, but not entered by the tide, to streams and ponds up to 700 feet above the sea level, and in every case but one, they belonged to the *var. gymnurus*; the one exception, *var. brachycentrus*, was obtained in a stream near Donemanagh, county of Tyrone, and measured three inches. From this, and probably from many others of our northern streams, the sprinkly-bag, as it is here called, has been almost entirely banished by the reprehensible practice of turning flax-water into the rivers; however, they still exist in numbers in the small streams, ponds, and drains, where this pollution does not occur.

Gasterosteus spinachia.—Known at Portrush as “horn-eel,” from a fancied resemblance to *Belone vulgaris*.

Labrus maculatus.—Called “rock-bream” at Bray, and “merrin” at Portrush, where *L. mixtus* is distinguished as “merrinroe.” They are specially sought for on the north-coast as bait for crab, lobster, and buckie-creels, and also for conger and deep-sea lines, the method employed being as follows:—Strong, but fine, boulders, known as “merrin lines,” baited with buckies and hermit-crabs, are set on a rocky weed-covered bottom, about an hour before the turn of the tide, and are taken up before the new tide has time to set down upon the line, since, should it do so, the masses of tangle on which the line rests, being reversed, would cover the line, and thus probably cause its loss, or at any rate strip it of all its hooks. The wrasses are also salted and kept for winter use both by the fishermen and country people living near the shore, and are considered good food.

Labrus mixtus.—Not uncommon at Portrush, where it is taken in the same manner as the preceding species. The largest example measured $12\frac{1}{2}$ inches.

Otenolabrus rupestris.—Mr. Blake Knox’s assertion (*Zoologist*, 1866, p. 506), that this wrasse is so abundant in Dublin Bay as to merit a local proverb and name must, I think, be looked upon with some suspicion. I have caught many dozens of small wrasses on the Dublin coast, but all were either *Crenilabrus melops* or the young of *Labrus maculatus*; and it is a significant fact that our National Museum does not yet contain a native specimen, though we would be only too happy to see it there. Barneleugh is on the coast of Northumberland, and Selby’s example was, therefore, English, not Irish.

Gadus morrhua.—Both the cod and the ling, *Molva vulgaris*, are greatly subject to blindness, the eyes of those thus affected being entirely covered with a thick bluish skin; this, however, does not in the least affect their condition. On the north coast the fishery is carried on from October to March inclusive, but usually all have spawned by the end of February. So sensitive are they to the approach of bad weather, that they leave the banks and retire to the deeper water outside, about three days previous to the commencement of a gale. The young, about an inch long, are common during June and July under *Medusæ* floating seaweed, &c. Those of medium size, from 3lbs. to 8lbs. in weight are called “half-guages” at Portrush, and “buddaghs” at Portaferry. During the winter of 1877–78 I caught a cod which had no trace of a pectoral fin on one side externally, but internally there was a hard lump. Cod taken on rocky or mixed ground are superior to those from sandy or muddy ground: probably owing to the more abundant supply of crustaceous food.

Gadus æglefinus.—Prior to 1865, haddocks were very numerous at Portrush, where the lines set for them were baited with various *Helices*. About that year they deserted this part of the coast, and did not appear again in any quantity till 1877, when shoals of small fish arrived during the summer, in company with whiting. The same desertion and return has been noticed in Dublin Bay. Larne Lough mostly supplies the Belfast market.

Gadus luscus.—Common at Portrush, frequenting rocky and weedy ground, and called “maggelagy.” Two, which I captured, measured—(1) Oct. 17, 1877: length $18\frac{1}{2}$ inches; weight 4 lbs.; prime. (2) July 20, 1878: length $18\frac{3}{4}$ inches; weight $3\frac{1}{2}$ lbs.; out of condition. Large examples, when prime, are quite equal to haddock and whiting for the table.

Gadus minutus.—Very common at Portrush, where it is confounded with the young of *G. luscus*, frequenting sandy spots near rocks and weeds. They are found in Kingstown harbour, east coast.—(A. G. More). I have seen no example exceeding six inches in length.

Gadus merlangus.—On the north coast the lines are always set, if possible, along the edge of the coarse ground, the best baits being pieces of garfish or launce, in lack of which whelks or hermit-crabs are used. Since Thompson’s time we have, I presume, had

our taste educated, as I always find whittings selling well, which occasions a regular fishery for them from October to January on parts of the Derry coast. After having been scarce for many years, they became abundant, along with the haddocks, in 1877.

Gadus poutassou.—In the *Dublin Nat. Hist. Soc. Proceedings*, 1865, vol. iv., p. 9, Mr. William Andrews records this fish, under the name of *Merlangus albus*, as having been noticed by him in the Claddagh market at Galway. But this specimen unfortunately was not preserved, and thus the identification remains doubtful.

Gadus pollachius.—The young, up to 6 inches long, are called “rackies” at Portrush. Young eels about 4 inches long, which have been steeped for some time in brine, form an excellent bait for whiffing, while boiled limpets and crabs are excellent for bottom fishing. My largest examples weighed — (1) 15 lbs., caught by whiffing, August, 1877; (2) 17½ lbs., caught on a cod line, March, 1878; (3) 21½ lbs., caught as preceding, April, 1878, in about thirty fathoms water.

Merluccius vulgaris.—So rare on the coast about Portrush, that I have never seen an example, and have heard of only one, which occurred many years ago.

Phycis blennioides.—The earliest authentic Irish record of this fish is Templeton's, who obtained it among haddock (in Belfast market?) on the 24th January, 1812. There is also an example in the Dublin Museum of Science and Art from the Ordnance Collection, but no locality or date is mentioned, though doubtless it came from the north of Ireland.

Molva vulgaris.—On the Derry and neighbouring coasts, ling and cod are sought for together, the fishery for conger being carried on in a different manner. The boutlers are here baited alternately with a slice of fresh fish and a whelk, the former being considered better for ling, the latter for cod. Young ling are caught frequently on the “merrin-lines” during summer and autumn at Portrush, generally about one foot long; and, as Thompson mentions and describes a young fish of about that length taken in January, it would appear that there must be a considerable variation in the date of their spawning at different localities. The season continues from December to April with us. In May they are little fished for, and are for the most part spent.

Motella mustela.—Not nearly so plentiful about Portrush as *M. tricirrata*, and only obtained of small size and between tide-marks.

Motella tricirrata.—At Portrush called “catfish” in conjunction with the last species. I have never known of one taking a hook, but numbers are caught in the wicker crab-pots during the spring months, when these are first laid down, their sense of smell being so powerful, that a very few days suffice to exhaust the locality. These examples, being all of large size, pay the penalty of their temerity by themselves forming a bait for the creels. Immature examples are often obtained in four to six fathoms water in the buckie creels in winter; these are unspotted to at least six inches long.

Raniceps raninus.—In addition to those mentioned by Dr. Day, I learn from Mr. A. G. More, that Mr. Andrews forwarded two other specimens to the Museum of Science and Art, Dublin:—(1) Dingle Bay—the second recorded by him from this locality—caught in thirty fathoms, 1856; (2) Dalkey Sound, June, 1856. My two recorded examples from Portrush have been confused: their records should run thus:—(1) Second week of November, 1875, length $8\frac{1}{2}$ in.; (2) 15th March, 1876, length $4\frac{1}{2}$ in.; these two are also in above-mentioned Museum. A third example, like the others, washed ashore dead, but in this case in a badly mutilated condition, occurred to myself on February 16th, 1878, at the same place. (For Sir J. Corrigan, read Sir D. Corrigan.)

Brosmius brosme.—This species should be omitted from the Irish catalogue, there being no reliable evidence of its occurrence. The name Torsk or Tusk is often given to codfish.

Ammodytes lanceolatus.—Frequently takes a small white fly (or a small strip of white leather.—A. G. M.), especially towards evening, when the shoals are drawing inshore to their usual hiding places. About two days after a severe N.-W. gale, which occurred in January, 1876, large numbers of this species were found on the east strand, Portrush, about fifty yards above high water-mark, buried in the sand, from which their heads protruded about an inch, having evidently being driven in to this unusual distance by the violence of the waves. I have seen several twelve inches long.

Hippoglossus vulgaris.—A few are taken yearly at Portrush

during the spring months. They are also used as bait for the deep-sea lines, as cod and ling are said to be very partial to their flesh. Small examples (up to 50 lbs.) are excellent as food. In the stomach of one taken in March, 1878, were several lumps of boiled beef and two large bones, the whole weighing nearly 8 lbs. Thompson mentions an Irish example from Ballywalter, in the county Down, which exceeded 300 lbs. Called "halibut" in the north.

Rhombus maximus.—With us, the bait considered best for turbot is a piece of the flesh of a conger which has been hung for several days in the open air, so as to become partly stale. The largest which I have obtained weighed 36 lbs. Legislation is greatly needed to put a stop to the reckless destruction of the young fry of this species and its allies by shrimpers. I have returned to the water thousands of turbot, britts, plaice, flounders and soles, by simply gathering up the leavings of these people.

Rhombus lævis.—Thompson's statement, that this species outnumbered its larger relative by about four to one, must be qualified as regards Portrush, for here the two species are about equally plentiful. On the 4th June, 1881, I obtained a very curious monstrosity. The head was horned, similarly to the specimen figured by Yarrell (vol. i., p. 643), but the protuberance was even longer, and the lateral line branched off anteriorly into two parts, one running forward to the end of the horn, the other bending downwards along the snout.

Zeugopterus punctatus.—In addition to those mentioned by Dr. Day, I have to record two examples obtained at Portrush, both taken in crab-pots:—(1) April, 1876, length $6\frac{1}{2}$ in.; (2) August, 1877, length $4\frac{3}{4}$ in. Thompson's two recorded Dublin examples—Carmichael's and Warren's—were not obtained in the market. (The Museum of Science and Art, Dublin, possesses a specimen from Dingle, county of Kerry, presented by Andrews.—A. G. M.)

Arnoglossus megastoma.—In June, 1881, I obtained in the Belfast market a small example, which had been forwarded with other flat fishes from Magilligan, county of Derry, and was the only one I ever saw from that district. The lateral line was shaped as in the figure of *Z. velivolans*, Yarrell, vol. i., p. 656. (Common in the Dublin market.—A. G. M.)

Arnoglossus laterna.—The hundreds mentioned by Mr. Blake Knox (*Zoologist*, 1866, p. 508) as landed in Dublin from trawlers, if correctly identified, may have been captured at a considerable distance, and do not necessarily belong to the Dublin coast. Andrews obtained specimens from Dingle and Ballinskelligs Bays, and forwarded one to the Dublin Museum of Science and Art.

Pleuronectes platessa.—"Spotty fluke" about Portrush. Out of two-score large plaice from Glenarm, county of Antrim, which I observed in the Belfast market on June 16th, 1881, no less than five were coloured on both sides; one of these was slate-blue, the orange spots, however, being on the upper side only. Very large examples, from 8 lbs. upwards, rarely take a bait, the stomachs of those which I have examined being invariably filled with shells. With the first fine weather in spring, large shoals of plaice, from 1 lb. to 3 lbs. in weight, draw inshore, and as they take a bait greedily, these "scull-flukes" are eagerly sought, a mixture of lug- and rag-worms, shrimps, razorfish, hermit crabs and cuttle, being used as a bait. I caught a very handsome example at Bray in August, 1872, in which the spots on the upper surface were exceptionally large and brilliant, while the under surface was beautifully marbled with white, buff, and olive green.

Pleuronectes microcephalus.—"Bastard-sole" at Portrush; "lemon-" and "maiden-sole" in the Belfast market, where it frequently occurs.

Pleuronectes cynoglossus.—Yarrell mentions a skin of one from the Firth of Forth measuring 19 inches.

Pleuronectes limanda.—On the 3rd November, 1877, I caught my two largest examples, measuring $14\frac{5}{8}$ in. and 14 in., and weighing $21\frac{1}{2}$ oz. and 18 oz. respectively. Dabs caught on mixed ground are of a finer flavour than those from sand or mud. They are used as bait for the conger lines, for which purpose they are unequalled, as also they are for lobster-creels; they are frequently caught with a piece of whelk, a bait which their congeners will rarely look at. I have never met with the fry of the dab among the debris of the shrimp-nets.

Pleuronectes flesus.—I kept two small flounders, taken from muddy ground, and therefore of an immaculate dark brown colour above, in a bath, the bottom of which was white, and in which no

foreign substance was placed, and within a week they had become pale grey, with some scattered brown spots.

Solea lascaris.—Seems to be rare on the Irish coasts; it has never occurred personally to either Mr. More or myself.

Solea variegata.—I may remark that in Thompson's specimen, obtained in Belfast Lough, 18th June, 1838, the rays of the D. and A. fins are in both cases less than the number given by Day, being only 63 and 49. In the *Ann. & Mag. of Nat. Hist.*, vol. vi., p. 405, Professor M'Coy states that this species is found in tolerable abundance off Dublin Bay, between the Kish lightship and the harbour.

Solea lutea.—The first example preserved, though not recorded at the time, seems to have been Ball's, from Youghal, county Cork, taken in October, 1834 or '35; (2) Three taken by Thompson and Hyndman off Dundrum, county Down, 23rd August, 1836; (3) Four by Hyndman in Belfast Lough, 18th June, 1838; (4) By M'Calla, off Dublin Bay and coast of Down, in or prior to 1840; (5) A few off Bundoran, Donegal Bay, by Thompson, July, 1840; (6) By M'Coy, along with the last species (which see); (7) Off the Dublin coast by Ball, no date given. The largest Irish specimen recorded measured $4\frac{1}{2}$ in., and two examined by Thompson had 76 rays in the D. and 58 and 59 in the A. fins, respectively, these numbers exceeding the maximum given by Dr. Day.

Salmo salar.—In the Foyle tributaries the fry of all the Salmonidæ, before putting on the migratory dress, are known as "jinkins." After the anadromous forms have assumed the silvery dress, simply as "fry." During the season of 1884, the fisheries in the Foyle above Londonderry were exceptionally poor, a fact which was partially attributed to artillery practice having taken place in that city at the time when the main body of fish were running up the river. In the summer of 1876 I saw a curiously deformed salmon taken at Portrush, which, owing to spinal disease, had the back so much humped that its girth in front of the rayed dorsal was exactly the same—19 inches—as its total length. During February and March numbers of small dark-coloured fish¹ run up the Burnden-

¹ Owing to the date of their appearance, I have never been able to obtain a specimen for examination; but it is possible that these may be a barren variety, similar to those observed in the Rhine by Barfurth.

net, a tributary of the Foyle in the county Tyrone, where they do great harm by rooting up the redds of larger fish, previously spawned, either in order to consume the eggs and fry, or to make their own redds. There can be little doubt that the fisheries would be improved if these and all other salmon remaining in the river were allowed to be caught after the 15th February, at which date the season might commence. On the other hand, the month of October might be advantageously added on to the close season, since the main body of the trout and sewin spawn during that month, and are certainly not in good condition for the table. After spawning is over, the kelts consume, on the average, at least a dozen fry per diem, almost all of which are young salmon and sewin, which are then dropping down the river. Granting that but one-half of these are salmon-smolts, every kelt which remains in the river for one hundred days after February 15th—not an inordinate assumption—consumes six hundred salmon-fry; reducing this number again by one-half, to allow for losses which might have occurred from other causes during the perils of migration, we arrive at a dead loss to the fishery of three hundred grilse, which, on their return in a few months, would have weighed about 1000 lbs. : against which we have only a single kelt, which, if it should have chanced to escape the dangers of the sea, would have returned the larger by 4 lbs. or 5 lbs. During the summer of 1875 I took from The Bush, county Antrim, a grilse of about 4 lbs., which was so completely covered with fungus that on the fins and part of the head alone was the skin visible; this fish was fresh-run, and taken not a mile from the sea. The following fact seems to prove that salmon do not invariably breed annually :—In January, 1878, numbers of salmon were seen, and one actually captured with a gaff, leaping and sporting on the surface, about five miles out to sea off Portrush, county Antrim. The captured fish proved to be in perfect condition, showed no signs of breeding, and could not therefore have intended so doing that winter. This, and presumably those in company with it, were Foyle fish, which are easily distinguished from those which ascend the Bann. The large salmon, too, which run up our rivers early in spring, could hardly have spawned during the preceding winter and so quickly have recovered their condition. It is probable that local, or even individual causes, which may be either temporary or persistent,

may induce fish to become annual or biennial breeders, according to circumstances. On the 30th April, 1883, I caught a small female salmon in Lough Ashe, county Tyrone, in which the ova were ready for extrusion. This Lough has no outlet to the sea, up which fish could make their way, and the individual in question was undoubtedly one of the number of fry put in from the adjacent stream just two years previously. There can be no doubt that this fish would have shed its spawn in the feeder of the Lough—at the very mouth of which it was taken—and it would seem to show that a small non-migratory race might be propagated in this and many other loughs, where there is sufficient space and food. The fish was in good condition, and as silvery as if fresh run from the sea; it is now in the British Museum, and has been examined by Dr. Day. During the spring of 1875 I saw three salmon in the Dublin market, weighing respectively 58, 55, and 53 lbs., and all three were said to have been taken at one haul of a net in the Shannon.

Salmo trutta.—Known in the north of Ireland as “white trout” only. The variety *cambricus* is alone found in our northern rivers, and of this we also have a long-headed and short-headed form—a difference, however, which will be found on dissection to be greatly attributable to sex, the short-headed being, as a rule, females, and of the two much the handsomer fish. Once only have I captured a “sewin” in the open sea, on a sand-launce, while whipping for pollock at night outside the Skerries, off Portrush. Of the fry placed in Lough Ashe, as mentioned above, in the spring of 1881, I took several in 1883, which proved to be “sewin”; they had increased in size to nearly 1 lb. average weight, had retained a more or less silvery colour, but had gained a few dark-edged red spots above the lateral line; they were, in May, in magnificent condition, and of flavour superior to the fresh-run autumn trout; two of them contained ova about the size of turnip-seed. The largest “sewin” which I have handled weighed $8\frac{1}{2}$ lbs.

Salmo fario.—The “estuary trout” of the northern rivers, which is here known as a “dolachan,” is, I believe, a large brook trout, which lives for the most part on small fishes, and resides during the greater portion of the year in the tidal reaches, making its way into the upper waters of our streams about October, where they feed principally upon the fry and eggs of their congeners, of which

they consume an incredible amount. They are seldom taken under 2 lbs. weight, and I consider these overgrown trout the worst enemy with which the salmon have to contend in these rivers, not even excepting an old male kelt. These "estuary" fish do not resemble any of the figures in Dr. Day's work, their colours being as follows:—For about two-thirds of the length below, and one-third above the lateral line, the body is thickly studded with *brick-coloured* spots about the size of a threepenny piece, the upper parts being covered with similarly-sized *brown* spots; while from head to tail there is a distinct lead-coloured longitudinal band, comprising about four rows of scales below, and two above, the lateral line.¹ These fish, though living so long in salt or brackish water, never assume a silvery appearance; in fact, some of the most brilliantly coloured and spotted trout that I have ever seen, were taken in almost pure salt water, close to the mouth of the Bann.

From careful examinations made during the last three years—1882-'84—I find that although about 70 per cent. of our brook trout breed during September and October, there is no month during spring and summer in which some do not shed their spawn.² While conducting the same series of observations, I have also arrived at the conviction that the size of the ripe ova corresponds to the size and age of the parent fish. Mr. Meenan, of Belfast, writes me that the largest Lough Neagh trout, which he has received of late years, weighed 27 lbs.

Salmo alpinus.—Among local names should be mentioned "murreen," by which, according to Wilde, they are known in several of the Galway and Mayo lakes. Charr are common in many of the Donegal loughs, and these loughs have no appearance of a glacial origin, and in some cases at least, as in the small bog loughs of Innishowen, they are nowhere deep. I do not think that we have any positive proof that the disappearance of this fish from Lough Neagh is due to the agency of man; and it is remarkable that their disappearance from Inchigeelagh and

¹ In a male, partially spawned, killed October 3rd, 1884, there is but one tooth on the head of the vomer, and an irregular double row, in which many were wanting, along the body of that bone, a slight mandibular hook, fifty-eight vertebra, and only thirty *cæcal appendages*; teeth largely developed.

² I have never had an opportunity of examining specimens from November to February, inclusive.

Gougaunbarra—the “lakes at the source of the river Lee” alluded to by Professor Allman—occurred about the same date, and that from Loch Leven not long afterwards. Though, judging from well-known habits in its congeners, it is probable that charr would gladly make a meal of trout-fry and -ova; still the breeding haunts of the two species are so diverse, that they can hardly do much damage. The lake near Dunfanaghy, mentioned by Templeton, is probably Sessagh, where Mr. Lucas, of Letterkenny, tells me they are found. To him I am also indebted for the locality of Lough Veagh in the same county; and Mr. Connison, of Londonderry, has taken numbers with the fly in the Mindorin and Minteagh lakes of Innishowen. In Westmeath, Lough Owel, and in Wicklow, Luggela, must also be added, while it appears that, in Cork, Inchi-geelagh should not be expunged from the list of localities. They have lately been introduced into Lake Gartinardress, county Longford: *fide* W. J. Hamilton. The usual size of Donegal examples is from 7 to 10 inches.

[*Osmerus eperlanus* might be omitted from the Irish list. There can be little doubt that Thompson’s conjecture as to confusion existing between this fish and the Atherine is correct.]

Coregonus pollan.—Dr. Day does not mention the occurrence of this species in salt or brackish water, though the fact is indisputable, as the following, from four distinct localities, will show:—Two of these localities are recorded in the *Field*. Whether their migration to salt water is unavoidable or intentional, remains an open question; but I certainly incline to the former opinion, believing that heavy floods, with which these fish are not strong enough to cope, have swept them to the sea, where they have lost their reckoning, and hundreds have probably perished, for one that attained to a safe resting-place. The first occurrence was recorded in the *Field* of January 5, 1878, by the late Mr. Francis Francis, who obtained his examples from the coast of Cheshire, between the mouths of the Dee and Mersey, where they appear to have been taken in considerable numbers; and in the following issue of the same paper the identity of his specimens with *C. pollan* is fully established on the authority of Dr. Günther, who personally examined them. Again, in the *Field* of January 19, 1878, Mr. R. G. Symes, of the Irish Geological Survey, records examples from the estuary of the Erne; it would seem also from

the wording of his letter, that pollan are found in Lough Melvin, and the Bundrowes river. In addition to these localities it is well known in the estuary of the Bann, and I now propose to give a short account of its recent colonization of the estuary of the Foyle. Here they appeared first in 1881, but were scarce and of large size, while, in the following season, they were slightly more plentiful, about a dozen being taken at each tide, and up to the ordinary standard of size; but in 1883 they were much smaller—all those which I personally weighed scaling from 7 oz. to 9 oz.—but infinitely more numerous, as many as 7 doz. being not uncommonly taken in a tide. In this year, positive proof of their breeding was obtainable, examples of about three inches long having been caught, and hundreds of others were seen to pass through the meshes. Owing to the unusual lowness of the river, consequent on the long drought, the season of 1884 proved exceptionally unsuccessful for all kinds of fishing, and it is not, therefore, surprising that the numbers of these fish which were taken were far less than in the preceding year; but it is remarkable that with the decrease of numbers the increase of size again became most marked. Nothing, however, was seen of those which were bred last year, nor any sign of this year's brood. The bay between Dunnalong and Magheramason points, on the Tyrone bank, is the only part of the river in which they seem to be permanently established, probably because at all states of the tide there is slack water there; it has for the most part a muddy bottom, but with occasional patches of stony ground. It is in this bay, about five miles above Londonderry that they bred in 1883. Odd examples are captured in the nets, further up the estuary towards Strabane. Whatever may be the opinion of the edible qualities of the Lough Neagh pollan, these brackish-water fish, when obtained perfectly fresh from the net, are of excellent flavour. So full are they of oil, when in condition, that after having been kept for a few hours, it will actually drip from them when hung up.

Belone vulgaris.—Horn-eel is the only local name now in use in the Portrush district; never, so far as I can ascertain, "spearing." Here they are common during the autumn, but are more solitary than gregarious. The nets used are loosely hung within a wooden frame, about one yard square, and are anchored in eddies. They are almost the best bait for whiting and sea bream. They

run up the Foyle estuary to at least as high as Culmore. I have a note of one captured by myself in October, 1878, of $34\frac{1}{2}$ inches in length. (At p. 148, line 15, "latter" should be changed to "former," since it is *B. oculus*, which wants the vomerine teeth.)

[*Carassius vulgaris*.—I do not know of any mention of this fish by Thompson.]

Gobio fluviatilis.—Add to localities: Dublin canals, and lakes and rivers near Killashandra, county of Cavan (W. J. Hamilton). For "Dodden" write "Dodder."

Leuciscus erythrophthalmus is very capricious in taking an artificial fly, occasionally snapping it up at every cast, and again on a day, to all appearance in every way similar, refusing to look at it, though rising in numbers all round it. I have found it best to use a single small bright fly, cast very light, and as soon as ever the fly lights upon the surface flick it off; a calm bright day is the more suitable: I have caught thirty-two small rudd within an hour in this manner. In Leitrim Lough, a small pond near Donemanagh, county of Tyrone, many of the rudd have the upper lobe of the caudal slightly shorter than the lower.

Leuciscus phoxinus.—I have never seen minnows more abundant anywhere, not even in the Itchen, than they are in the main river and Kellswater, near Bellaghy, county of Antrim. Mr. W. J. Hamilton also tells me that they are common in some of the rivers of Cavan. I think that the theory of its introduction is excessively doubtful; its scarcity is more probably due to the nature of the country.

Abramis blicca.—Not being found in Ireland, it seems probable that the local names given belongs to *A. brama*.

Nemacheilus barbatula is unfortunately quite as good a bait on night-lines for large trout as for eels; numbers are thus caught in the rivers near Omagh: the county of Tyrone may, therefore, be added to the list; as also may Kilkenny, Wexford, Clare, and Galway.

Clupea alosa?—A fish called the "craig herring" is taken in the Foyle during the latter part of June and July: sometimes as many as eight in a tide. This year, 1884, only one was taken, which I failed to see. As it is said to grow to 5 lbs. weight, I presume that it must be this species, rather than *C. finta*.

Anguilla vulgaris.—In our rivers eels do not as a rule hiber-

nate ; at least I have caught numbers of all sizes by setting night-lines in deep still holes during each of the winter months. Here, in the north, the skins are considered excellent as bandages in cases of sprain. Since forwarding the note published by Dr. Day—vol. iii., p. 249—I have examined several specimens from the Burdennelt, which are exactly intermediate in the measurements, as given in the last edition of Yarrell, between the so-called *A. latirostris* and *A. auctirostris*. Alluding to the mortality among eels in the *Lagan*—vol. iii., p. 243—Thompson is misquoted: he does not say the “three previous days,” but “three successive days in the previous month.”

Conger vulgaris.—Congers are sought for at all seasons on the north coast, but more especially in spring and autumn. During the winter they are often taken on the cod-lines set some distance off shore, and these examples are never more than 20 lbs. in weight, and are always light-coloured. They are known as “scull-congers,” and their appearance is always hailed with much satisfaction, not only because they command a higher price in the market than cod and ling, but also that when cut up they form the best bait for, and are supposed to denote a plentiful supply of, those fish. The fat round the intestines is used as an external remedy in cases of rheumatism and kindred diseases, being rubbed well into the parts affected. Large ones, preserved with brown sugar and pepper, and dried in the sun, are excellent if cut thin and fried like bacon. Thompson only mentions £3 as the value of nets destroyed in a single night, not £5. I am told by a trustworthy fisherman, who was present at its capture, that one of over 90 lbs. weight was left stranded by the receding tide at Prehen, about two miles above Londonderry, some thirty years ago: the largest he has since seen was taken in a salmon net three miles higher up the river, and weighed 53 lbs.

Siphonostoma typhle.—Might not this be noted as very rare in Ireland?

Nerophis æquoreus.—I have seen one of 31 inches length.

Nerophis ophidion.—The only two Irish examples certainly known are those mentioned by Thompson, under the head of “straight-nosed pipefish,” from the coasts of Down and Antrim. Those recorded as “snake pipefish” belong to *N. æquoreus*.

N. lumbriciformis.—I must demur to Thompson’s statement,

that this species and *S. acus* are “by far the most common pipe-fish” on the Irish coast; for, according to my experience, *N. æquoreus* outnumbers the two together by two to one, at least.

Tetrodon lagocephalus.—For “Tranmore,” read “Tramore.”

Orthogoriscus mola is uncertain in its visits to the north coast. Occasionally it appears to be common, as in 1876; but from that date till 1879—when I left Portrush—I did not see a single one. During the summer of 1876 one over 5 ft. long was caught in the salmon nets.

Acipenser sturio.—About a dozen are got annually in the salmon nets of the Foyle estuary. The largest which my informant (Mr. Wm. Donaghy, of Dunnalong) remembers to have seen measured 9 ft. 2 in., and was sent by the Fishery Company to London for use at the Queen’s coronation dinner.

Carcharias glaucus.—For “Nymph brand,” read “Nymph bank”—this is off the coast of Waterford. I am afraid that Mr. Blake Knox has overstated its abundance in Dublin Bay (see *Zoologist*, 1866, p. 509).

Galeus vulgaris.—Locally “famrie” on north coast.

Alopias vulpes.—That this species is “often very common in Dublin Bay,” as stated by Mr. Blake Knox, cannot but be erroneous. That no specimen has ever been captured there, and no competent ichthyologist ever recorded it from so thoroughly well-known a locality, speaks for itself.

Scyllium canicula is commonly eaten by the poorer classes about Portrush, and esteemed superior to the piked dog, which is also largely consumed. It is equally common in summer and winter, and feeds quite as much by day as by night.

Acanthias vulgaris.—I can quite vouch for the boldness of this horrid fish; many a time I have amused myself, while my fisherman was hauling the deep-sea lines, by gaffing the “goboy” as they swam round the boat, in readiness to seize anything which might fall off the hook while coming up; and more than once I have seen the whole pack, perhaps as many as a score, start like hounds after a ling or cod which had managed to struggle clear of the hook. There is no doubt that the wound caused by the dorsal spines is excessively painful, and frequently suppurates; but perhaps the continual wetting with salt water may induce, or at least

increase, the latter. Although they eat about a third of the hooked cod and ling, I never knew a conger to be touched.

Torpedo nobiliana.—In his summary of the two species (p. 331), Dr. Day correctly mentions the difference in the comparative sizes of the dorsal fins in the two British species, but these are not shown at all in his figures; or, if anything, are more prominent in *T. marmorata*.

Raia batis.—"Caillach" on the north coast is, next to the thornback, the most abundant species about Portrush. By connoisseurs in skate small "caillachs" are considered almost the equal of "thornies" for eating fresh; while large examples are said to be infinitely the best for, if not the only ones worth, salting. I have taken a thornback of $7\frac{1}{2}$ lbs. weight from the stomach of one of these fishes. I must exonerate the fishermen of the north coast from so grave a charge of laziness (see Day, vol. ii., p. 337) as that of cutting their lines in order to save themselves the trouble of unhooking fish caught by the pectoral fin, which a slight cut of a knife would do; but I have known large examples thrown overboard, and sometimes even cut adrift, in order to lighten an open boat in a heavy winter sea. In my experience of the capture of many hundred skates of all sorts, I never knew of a single example being caught by the pectoral fin. They will take greedily whelks and any kind of fish cut up as bait, and are sometimes quite a nuisance on the deep-sea lines.

Raia fullonica.—Only captured on the deep-sea lines in winter. It is not at all uncommon at Portrush, where it is locally known as the "piper," and is considered fair eating. The largest that I have caught measured 42 inches. The teeth in a female example, examined March 29th, 1878, were as sharp-pointed as those in males captured on the same day, strong and slender in both.

Raia clavata.—Enormous numbers are taken in summer on Magilligan strand, both by trawl-boats and by lines baited with sand-eels or fresh herrings. They are shipped fresh to the Liverpool market. It is by far our most abundant species, and most prized as food. When in good condition and cooked in a similar manner, it can hardly be distinguished from dressed lobster.

Raia maculata.—The "bengore skate" of Lough Foyle. Common in winter, and found in deeper water, with a rougher, bed than the preceding; considered worthless as food.

Raia circularis.—This species is not uncommon on the bank off Portrush, where it is taken on the winter cod-lines. I have notes of ten caught in my own boat between December, 1877, and October, 1878, inclusive; of these, seven were females. In the largest example— $38\frac{1}{2}$ inches total length—the pectoral blotch was absent, and, in its place, were eight white dusky-margined ocelli, placed in regularly corresponding pairs, on the opposite sides of the disk: this specimen weighed $13\frac{1}{2}$ lbs. In the nine others, which correspond to the “sandy ray” of Couch, the blotches were present, and one of them measured 30 inches over all, and weighed nearly 7 lbs. There can be no doubt of their specific identity. I think it probable that old individuals lose the blotch characteristic of the small examples.

Trygon pastinaca.—It must be observed that no competent ichthyologist—and we have had many good observers on all sides of our island of late years—speaks of having *personally* examined an Irish example. I would, therefore, reject it *in toto* from our list, which is far too much filled up with species of whose occurrence and identification there is no sufficient proof.

Myliobatis aquila should certainly be omitted for the same reasons.

Petromyzon marinus.—Common in the Foyle; but invariably thrown away.

Petromyzon fluviatilis.—I know of no Irish rivers in which this species is found.

Petromyzon branchialis.—Is found in streams and mill-races, lying on the southern water-shed of the Foyle. On one occasion I got a lampern adhering to a cod taken in 20-fathom water at a considerable distance from the shore, which, when examined, proved undoubtedly to be this form, with undivided dorsals.

Branchiostoma lanceolatum.—There is a mistake about my specimens (mentioned on p. 366). They certainly could not have belonged to this species, as the eyes were easily visible. I considered mine to be much more likely a *Leptocephalus*.

Schedophilus medusophagus.—For “south coast” read “north coast,” and see *ante*, p. 515.

LXXIV.—NOTE ON THE BLASTODERMIC VESICLE OF MAMMALS. BY ALFRED C. HADDON, M. A., M. R. I. A.,
Professor of Zoology, Royal College of Science, Dublin.

[Read, June 15, 1885.]

HAVING recently had occasion to refer to the development of mammals, it occurred to me that the significance of the so-called "blastopore of van Beneden" might be capable of elucidation. I therefore beg to offer the following note on the subject which may tend towards that object.

The following is a brief account of the segmentation of the rabbit's ovum, as described by Ed. van Beneden (3, 4, 5):—

Within an hour or two after fertilization the ovum commences to segment; the whole process of segmentation occupies from seventy to seventy-five hours, by which time the ova have just entered into the cavity of the uterus.

The ovum divides into two nearly equal spheres; the larger is clearer and somewhat differently acted upon by reagents than the other. Van Beneden believes that this indicates a fundamental difference between the two cells; the larger cell representing, according to him, the "ectoderm," and the smaller granular cell the "endoderm." In Quain's *Elements of Anatomy*, vol. ii. (9th edition, 1882), p. 744, they are spoken of as "upper" and "lower" spheres respectively; but in the description of the figures (figs. 630-1) "ectomere" and "entomere," Heape adopts the preferable plan of simply terming them and their derivatives "outer" and "inner" spheres.

Further segmentation into four and into eight spheres occurs in the usual manner. As is usually the case in holoblastic ova, the early-formed spheres are more or less spherical, and directly the third stage has been completed, the eight spheres lie in two tiers of four each in the ordinary manner; but very shortly one of the inner spheres passes into the interior of the mass, and the whole ovum regains its spherical contour.

The fourth stage is marked by the segmentation of the outer cells only, the blastula now consisting of eight outer cells and four

inner cells, the former being smaller than the latter, and tending to enclose them.

The inner cells next divide, forming thirteen cells in all, and become markedly more opaque and granular; four of these cells pass into the interior of the mass.

Further subdivision of the outer cells into sixteen cells causes them to extend still further over the inner cells.

Segmentation continues in both sets of spheres till the tenth stage is arrived at, when the ovum consists of a solid central mass of thirty-two inner cells, entirely surrounded by sixty-four outer cells, except at one spot which van Beneden calls the "blastopore." The outer cells, however, soon entirely surround the inner.

A cavity makes its appearance between the outer and the inner cells at the opposite pole of the ovum to that at which van Beneden's blastopore is situated. This cavity rapidly enlarges, and the inner cells depend as a small mass from one pole of the ovum.

About ninety-four hours after fertilization the ovum measured 0.28 mm., the diameter having tripled within the twenty-four hours since the ovum entered the uterus. It now consists of a thin walled vesicle, the blastodermic vesicle, the wall of which consists of a single layer of flattened cells, the products of the outer spheres. At one pole the inner cells form a flattened disc, the centre of which is two or three cells thick; the periphery is constituted of several rounded and more or less completely isolated cells. Later, these two portions of the inner mass become more distinguishable; the more coherent central portion initiates the circular embryonic area (*area pellucida*), while the irregular outer zone is formed of a single layer of amœboid cells, and gradually extends over the inner surface of the blastodermic vesicle, constituting the *area opaca*.

During the fifth day the blastoderm consists of three layers, which van Beneden regards as the three embryonic layers. He tabulates them thus (p. 179):—

Stage V. (102 hours, or four days, six hours).

Stage VI. (124 hours, or five days, four hours).

V.	VI.
<i>Ectoderm</i>	= <i>Epiblast</i>
<i>Endoderm</i>	= { <i>Mesoblast</i> + <i>Hypoblast</i> .

In other words, the diploblastic fifth stage is succeeded by a tri-

ploblastic sixth stage. Although van Beneden makes this assertion, he does not prove it, and he gives no sections in support of his statement; so I take it we are at liberty to doubt this identification, as it lands us in so much difficulty. The upper layer is formed of the flattened outer cells of the blastodermic vesicle, and the lower layer, which is the true hypoblast, also consists of flattened cells, which are continuous outside the embryonic area with the zone of amœboid cells which is creeping round the blastodermic vesicle. Between these two layers is a third layer of rounded cells (Mesoblast of van Beneden), which is now recognized to be the embryonic epiblast.

Kölliker (12) regards the outer-layer as protective and belonging to the blastodermic vesicle, and the middle layer to be the true epiblast, and the deepest layer the hypoblast. He states that the outer layer disappears, the epiblast becomes columnar, and that the mesoblast develops later in connexion with the primitive streak.

Rauber (16) also believes that the outer layer of the blastoderm of the rabbit ("Deckschicht" or covering layer) early disappears, and that the epiblast is derived from the inner mass.

Balfour and Heape (2, ii., p. 181), found on the sixth day that the embryonic area is throughout composed of—

1. "A layer of flattened hypoblast cells.
2. "A somewhat irregular layer of more columnar elements, in some places only a single row deep, and in other places two or more rows deep.
3. "Flat elements on the surface, which do not, however, form a continuous layer, and are intimately attached to the columnar cells below."

They believe they have in many instances been able to trace the flattened elements in the act of becoming columnar. Later, Heape (10) has afforded additional evidence for the rabbit, and has also shown it for the mole.

Lieberkühn (14), from his researches on the dog and mole, also believes that the epiblast is formed from the superficial portion of the inner mass, together with the overlying outer layer, after the differentiation of the hypoblast from the former.

Kupffer (13) finds that in the field-mouse (*Arvicola*) the covering layer (Deckschicht), which is by-the-by attached to the uterine

wall, is the seat of a rapid and early proliferation which pushes the embryonic area into the blastodermic vesicle. The underlying embryonic area alone enters into the formation of the embryo itself, the epiblastic layer of which consists, apparently from the first, of a single layer of cells.

In the earliest stage of the rat, figured by Fraser (8), six days, eight hours after impregnation, the blastodermic vesicle is elongated, and its cavity is greatly reduced by the projection of a solid mass of epiblast cells which projects into the cavity of the vesicle; the inner aspect of these cells is lined by a single layer of hypoblast. A well-marked layer of rounded cells (covering cells, Deckenzellen) occurs at the placental pole of the blastodermic vesicle. In twenty-four hours the epiblast forms a single layer of columnar cells enclosing a central cavity, the neuramniotic + the false amnion cavity. The Deckenzellen have by this time greatly increased in number.

From the above it is quite clear that the outer cells of the fully segmented mammalian ovum correspond to the epiblast of the area opaca, or yolk-blastoderm, and that the epiblast of the embryo is formed from the upper portion of the inner mass, the lower portion giving rise to the hypoblast. There is still some discrepancy as to the fate of the outer or covering cells which grow over the "blastopore" of van Beneden, and which form the flattened upper layer of the rabbit's blastoderm. According to Balfour (rabbit), Heape (rabbit and mole), and Lieberkühn (dog and mole), this layer enters into the formation of the embryonic epiblast; Kölliker and Rauber believe it disappears in the rabbit; Küpffer (*Arvicola*) and Fraser (rat and mouse) assert that the rounded cells of this layer become attached to the decidua, and do not form any portion of the embryo proper.

A consideration of these facts has led me to the view that we must recognize in the inner mass a germinal disc perfectly comparable with that of the fowl during the later stages of segmentation (cf. *The Elements of Embryology*, by Foster and Balfour, 1883, fig. 8, p. 22), which has sunk into the blastodermic vesicle owing to the absence of yolk. The outer layer corresponds to those epiblast cells which are gradually enclosing the yolk, the so-called blastopore of van Beneden indicating in an exaggerated manner the distinction between the embryonic and non-embryonic germinal layers.

Haacke (9) and Caldwell have recently demonstrated that the previously known (*cf.* W. B. Spencer, "The Eggs of Monotremes," *Nature*, xxxi., p. 132, December 11, 1884) but discredited fact that the Monotremata are oviparous, and that the eggs are perfectly comparable with those of reptiles. Thus Balfour's deduction, from purely embryological data, that the mammalian ovum originally possessed a large quantity of food-yolk, has been thoroughly verified.

Van Beneden has shown that this "blastopore" is a marked feature in the ovum of a rabbit. Balfour (2, fig. 134A, p. 178) and Allen Thomson (in Quain's *Anatomy*, ii., 1882, fig. 631A, p. 744) have reproduced the stage just before it is closed over, and thus do not show it at its greatest development. Van Beneden and Ch. Julin (6) figure a segmented ovum of the great horse-shoe bat in a very similar stage (woodcut, fig. 1), the chief differences being that in the former the outer cells are quadrate and not somewhat flattened; the inner mass entirely fills up the cavity of the blastodermic vesicle, instead of there being a considerable cavity as in the bat. In the former, the cells of the inner mass are well defined, whereas in the latter "it is impossible to distinguish the limits of the cells;" and, lastly, "the break in the continuity of the ectoderm, occupied by several 'endodermic' cells, appears to be homologous with the 'blastopore' of the rabbit; it is here of much greater extent and persists longer. In the rabbit it nearly always closes before the blastodermic cavity commences to form."

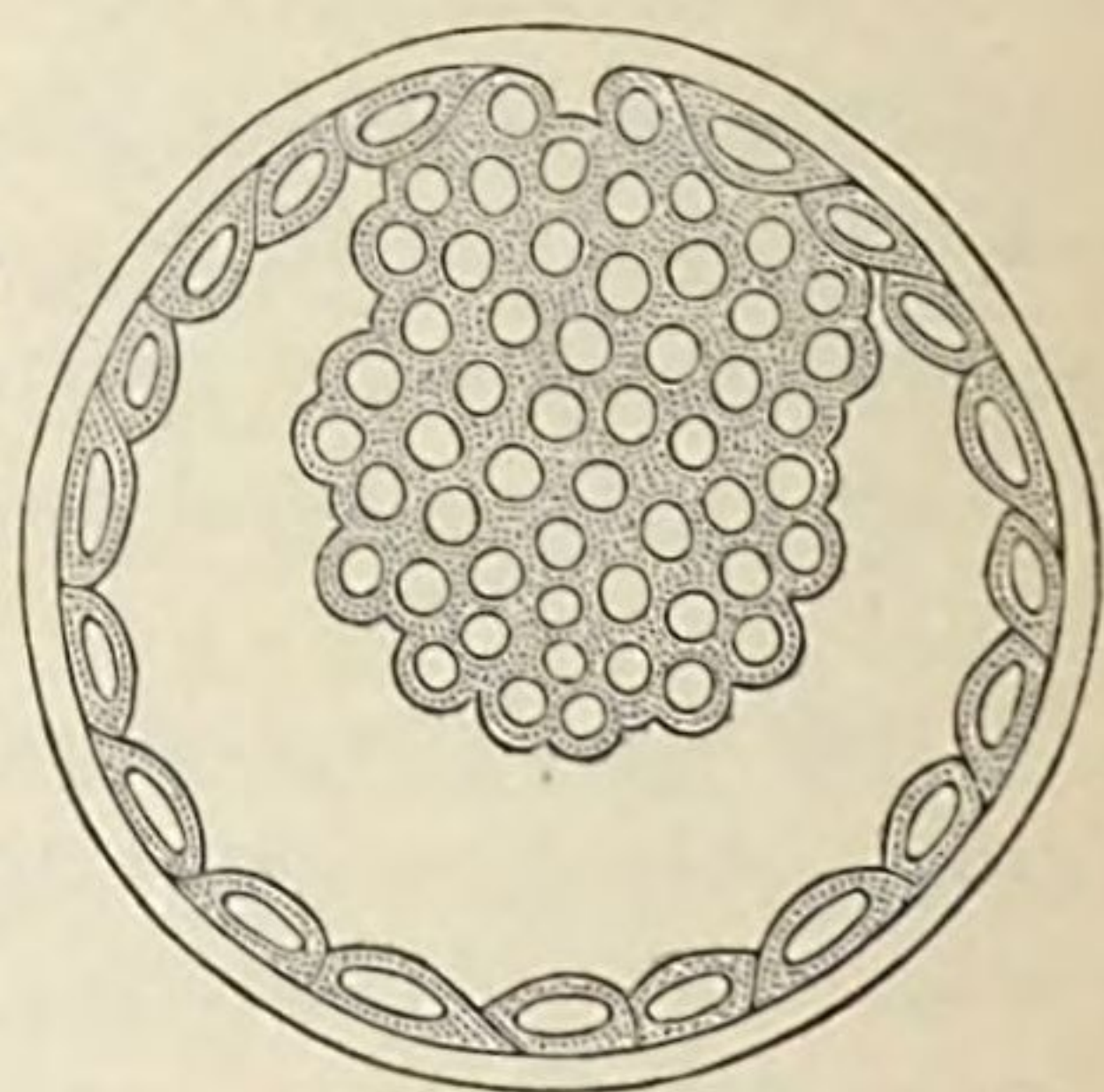


Fig. 1.—Blastodermic vesicle of the great horse-shoe bat (after van Beneden and Julin).

In the earliest stage of the mole, figured by Heape (10), the size of this "blastopore" and the general appearance of the ovum sufficiently resemble the last stage of the rabbit's "blastopore" mentioned above.

Dr. A. Fraser informs me he has not yet satisfied himself as to the presence of such a "blastopore" in the rat or the mouse.

The accompanying diagrams (figs. 2-5) may render this view more clear. Fig. 2 represents the ovum of a hypothetical primitive mammal (the monotreme's ovum is doubtless very similar to

this) in which the yolk is still present, and the yolk is partially

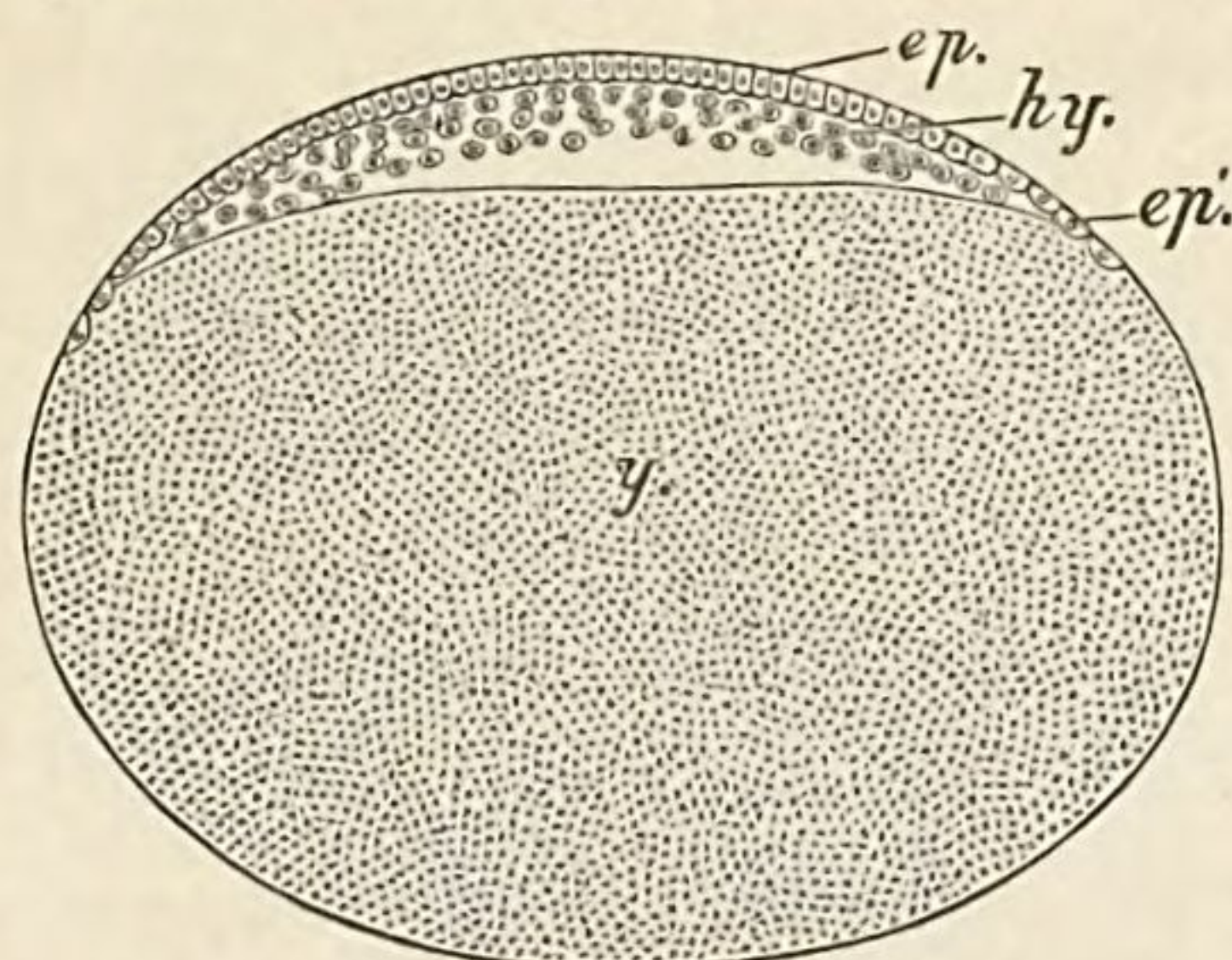


Fig. 2.

Diagrammatic transverse section through the blastoderm and yolk of the ovum of a hypothetical primitive mammal. *Ep.* embryonic epiblast; *ep'* non-embryonic epiblast, *i.e.* the epiblast of the area opaca; *hy.* hypoblast; *y.* yolk.

surrounded by the yolk blastoderm, the blastoderm itself consisting of an epiblastic layer and lower-layer cells. In fig. 3 the

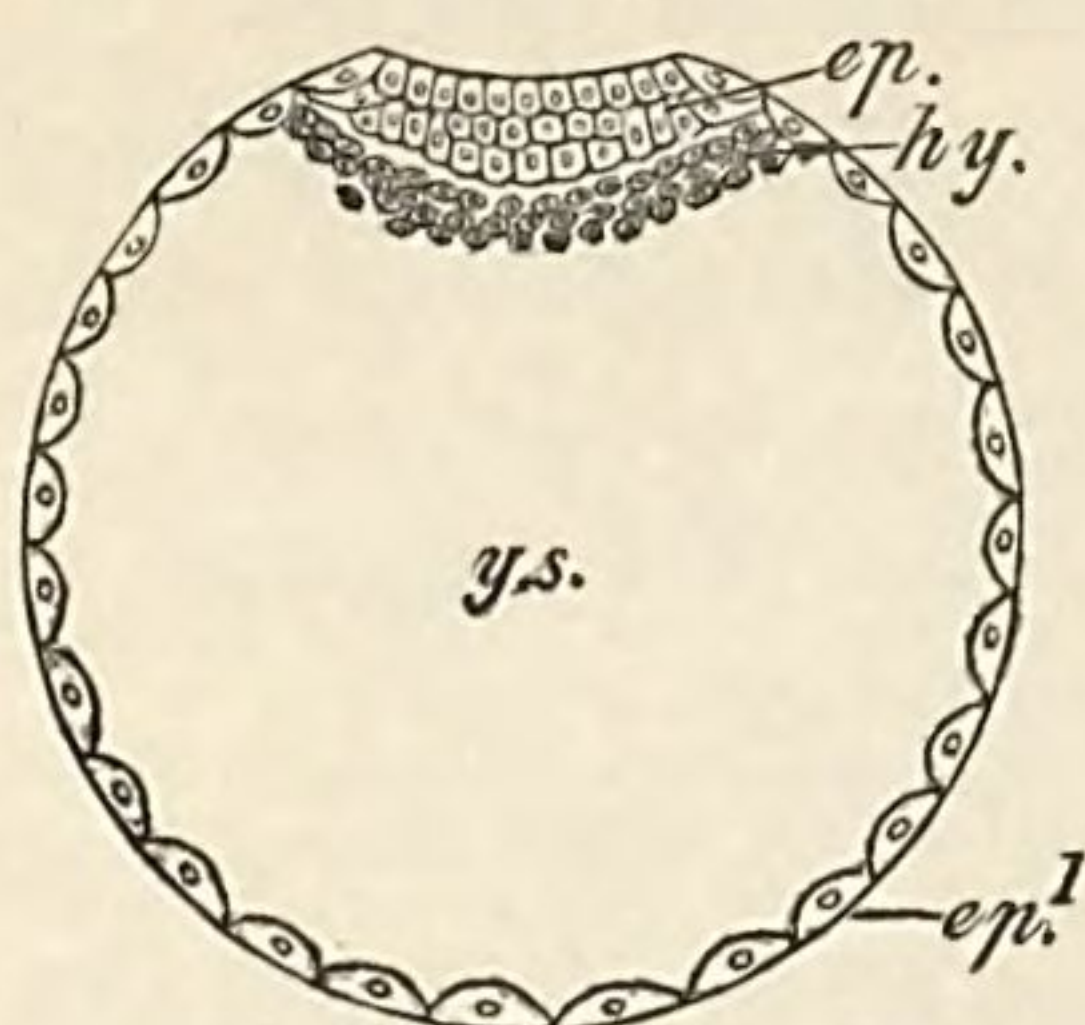


Fig. 3.

Diagrammatic transverse section of a hypothetical mammal's ovum, at a stage corresponding to Fig. 1. The yolk of the primitive mammalian ovum is now lost.

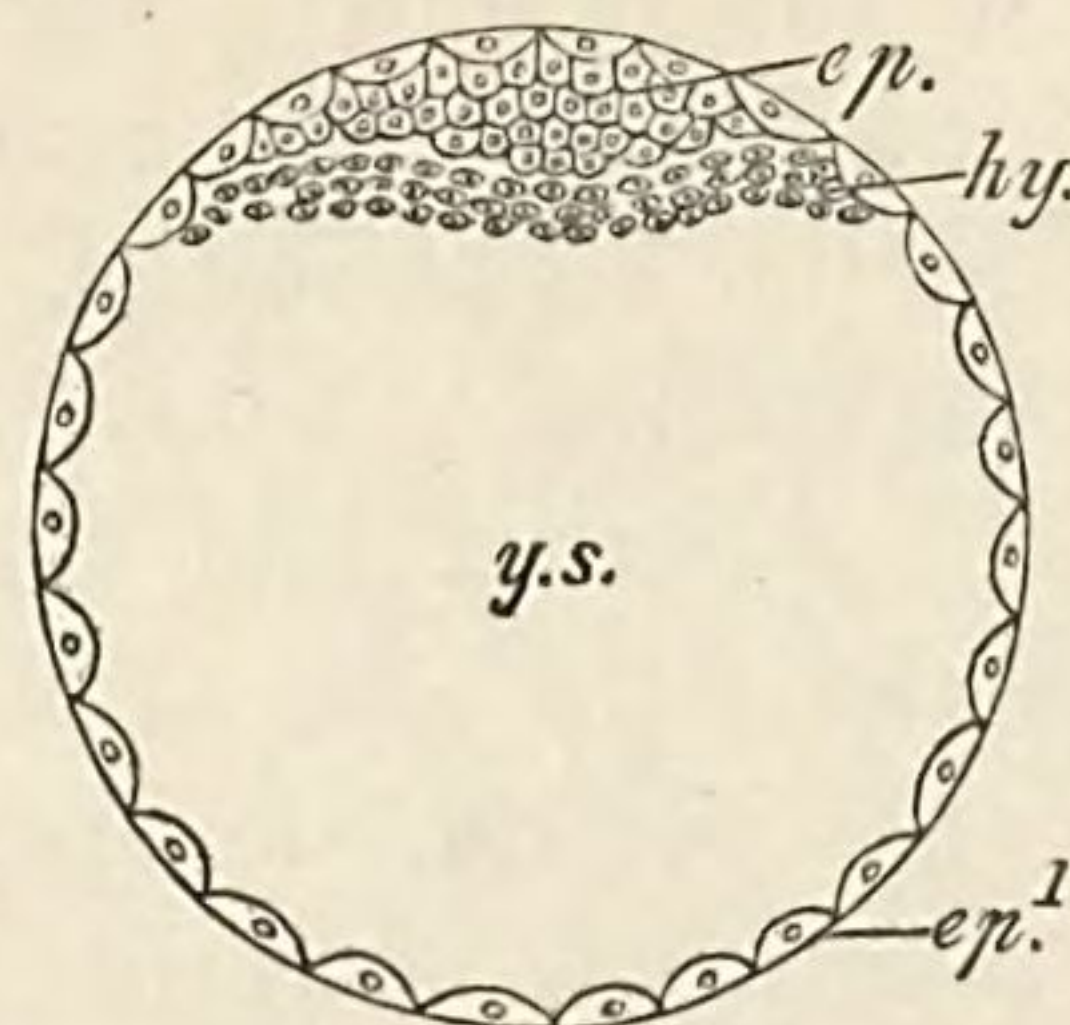


Fig. 4.

A later stage than fig. 3. The non-embryonic epiblast *ep'* has now grown over the embryonic area to form the covering cells. Lettering as above—*y. s.* yolk sac.

yolk is supposed to have been lost, and owing to its absence the yolk blastoderm, *i.e.* outer cells, have completed the blastodermic

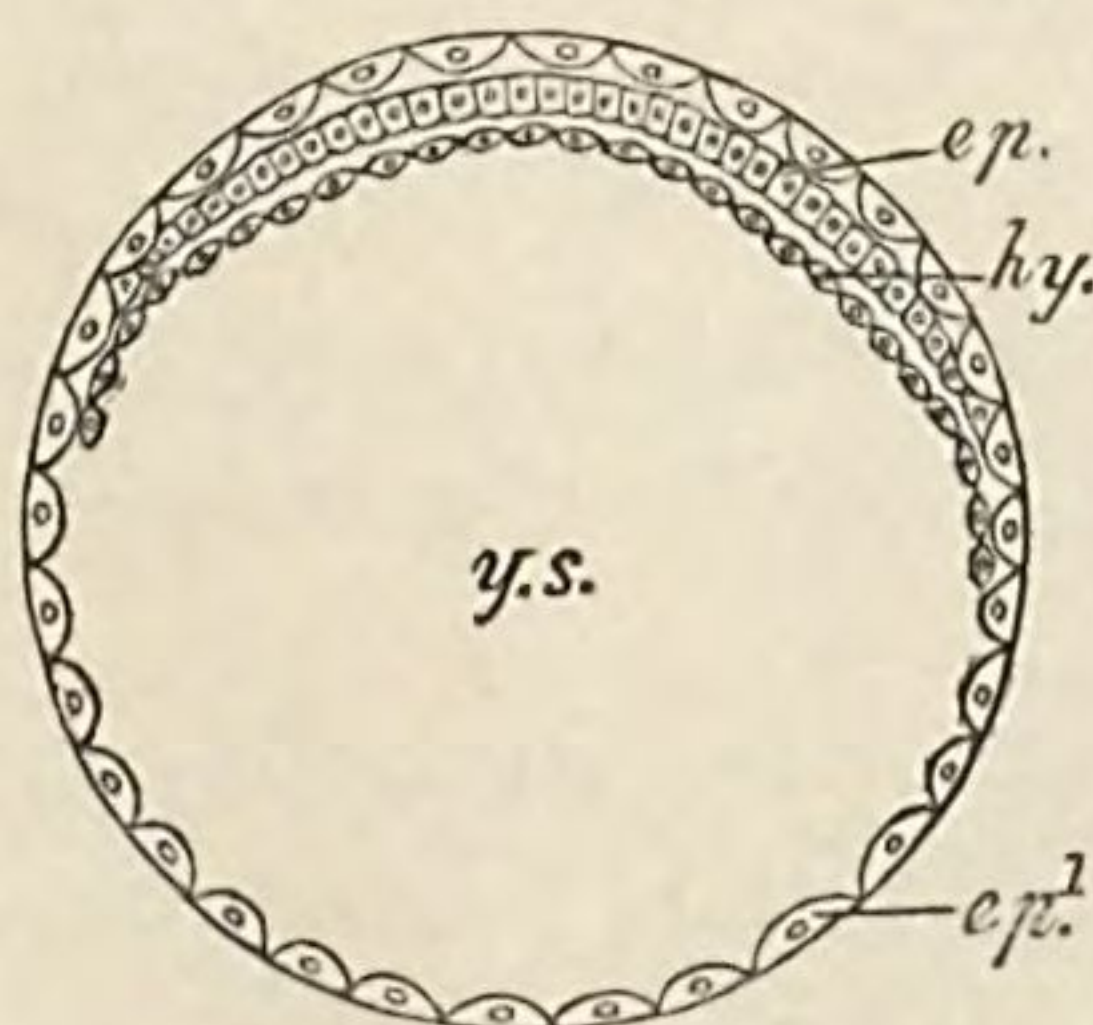


Fig. 5.

Diagrammatic section of a mammalian blastodermic vesicle, in which the primitive invagination of the blastoderm is rectified, and the covering cells have extended over the blastoderm. Lettering as before.

vesicle, and the blastoderm has sunk within the vesicle. This prac-

tically corresponds to the ovum of the bat figured above, fig. 1. In fig. 4 the yolk blastoderm has grown over the embryonic area, forming the covering cells (Deckenzellen). Lastly, in fig. 5, the invagination of the embryonic area is rectified, and there is a diploblastic ovum, the covering cells (Deckenzellen) forming the spurious third layer which misled van Beneden.

If the above interpretation be correct, it further follows that we have a very abbreviated segmentation occurring in the mammalian ovum. Accepting van Beneden's very precise statements, the inner mass (germinal area) is derived from one of the two primary segmentation spheres, the blastodermic vesicle being derived from the other. In other words, the first cleavage furrow demarcates the embryo from the yolk-sac.

Embryologists are now paying considerable attention to the orientation of the primitive segmentation spheres.

Agassiz and Whitman (1) have quite recently given a very careful account of the segmentation of some pelagic eggs of certain Teleostei (*Ctenolabrus*, *Pseudorhombus melanogaster*, *P. oblongus*, and *Tantoga*), and they find that the first cleavage plane corresponds with the long axis of the future embryo. It is a well-known fact that the nuclear spindles of one cell-generation tend to arrange themselves at right angles to those of the preceding generation. The primary spindle (archiamphaster), during division to form a polar globule, almost invariably coincides with the axis of the ovum (*i.e.* is radial); hence the first cleavage spindle usually assumes a position perpendicular to this axis (*i.e.* is bilateral), and the corresponding cleavage falls in a meridian plane which coincides with the median vertical plane of the embryo. . . . "We would carry the generalization one step farther, and say it is highly probable that *the first cleavage spindle invariably lies at right angles to the axis of the ovum throughout the metazoa, and that therefore the first cleavage plane is always a meridian plane*, at least in all cases where the first cleavage spindle is accompanied by cleavage" (p. 33).

Concerning the mammalian ovum, they say: "The researches of van Beneden on the maturation, fecundation, and cleavage of the mammalian ovum, of which we have thus far received only a preliminary account, leave it doubtful whether the first cleavage spindle is parallel with the axis of the ovum or at right angles to it. He calls attention to the pronounced polarity of the ovum, but expressly

states that he has not yet obtained a complete history of the first cleavage spindle. The relation of the plane of first cleavage to the axis of the ovum is therefore undetermined. If the first cleavage divides the ectodermic from the entodermic pole, as supposed by van Beneden, it is most probably equatorial. If further researches prove that the cleavage begins with an equatorial groove, a very important exception to the general rule will be established. If, on the other hand, it turns out that the first cleavage is meridian, it will be difficult to reconcile this fact with van Beneden's opinion on the destination of the first two cleavage-spheres" (pp. 36-7).

Remembering the great disturbance to normal segmentation, which must result first from an increase in the amount of food yolk, and secondly from its loss, it is not surprising that the segmentation of the mammalian ovum apparently forms an exception to the general rule—an exception, moreover, which would but emphasise the rule.

Hoffmann (11) states that he has observed in the ova of certain Teleosts (*Scorpæna*, *Julis*, &c.), the axis of the primary nuclear spindle (archiamphiaster) is identical with that of the ovum; and when two nuclei have been formed, both lie in this plane, the subsequent cleavage results in the division of the egg into two very unequal portions, an upper and smaller "archiblast" (germinal disk), and a very much larger "parablast" (yolk). "The archiblast alone segments, its nucleus is the parent of all the cleavage nuclei; the parablast does not segment, nuclear division only takes place within it; it is altered into a multinucleated cell." Agassiz and Whitman discuss Hoffmann's conclusions so keenly that until further evidence is forthcoming we can only accept their view of Teleostean segmentation.

Ryder (17, 18) supports Hoffman's conclusions, but without giving a sufficiently precise account of his own observations on the point.

There can be but little doubt that the first immigration of blastopheres into the interior of the ovum (van Beneden's stage 3) indicates the gastrula stage. It would further appear that this immigration was asymmetrical, much as there is an asymmetrical invagination of the hypoblast in telolecithal ova.

Unfortunately, van Beneden's is the only account we possess at the present time of the segmentation of the mammalian ovum.

When this process has been described in forms other than the rabbit, we shall be in a position to see how far the development of this rodent agrees with or differs from that of other mammals.

The extension of cells of the blastodermic vesicle over the embryonic area is probably to be accounted for in most cases by the sinking of the latter into the cavity of the former. I have previously alluded to the various views which are held concerning their fate. These Deckenzellen are really a portion of the blastodermic vesicle, that is, of the yolk-sac, and *they form the first adhesion between the ovum and the parent*.

It has recently been demonstrated that in marsupials the yolk-sac forms (at all events at first) the only adhesive surface of the embryo. Osborn (15) states that in the Virginian opossum (*Didelphys virginiana*), and in other unnamed forms from Australia,

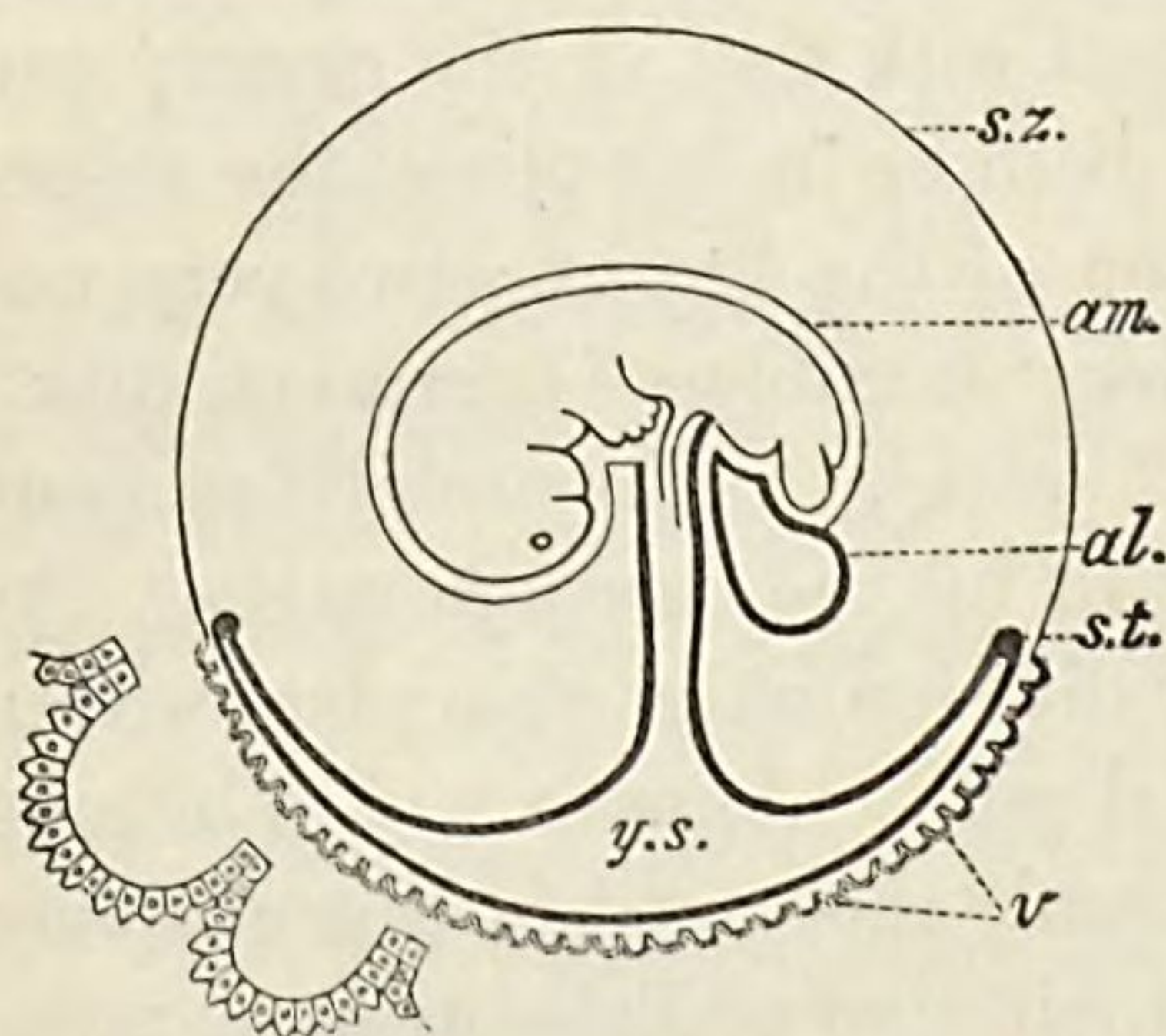


Fig. 6.

Diagram of the foetal membranes of the Virginian opossum (*D. virginiana*) with two villi greatly enlarged. The processes of the cells of the villi have been drawn too large and too numerous; they doubtless correspond to the pseudopodia described by Caldwell.—After Osborn, slightly modified.

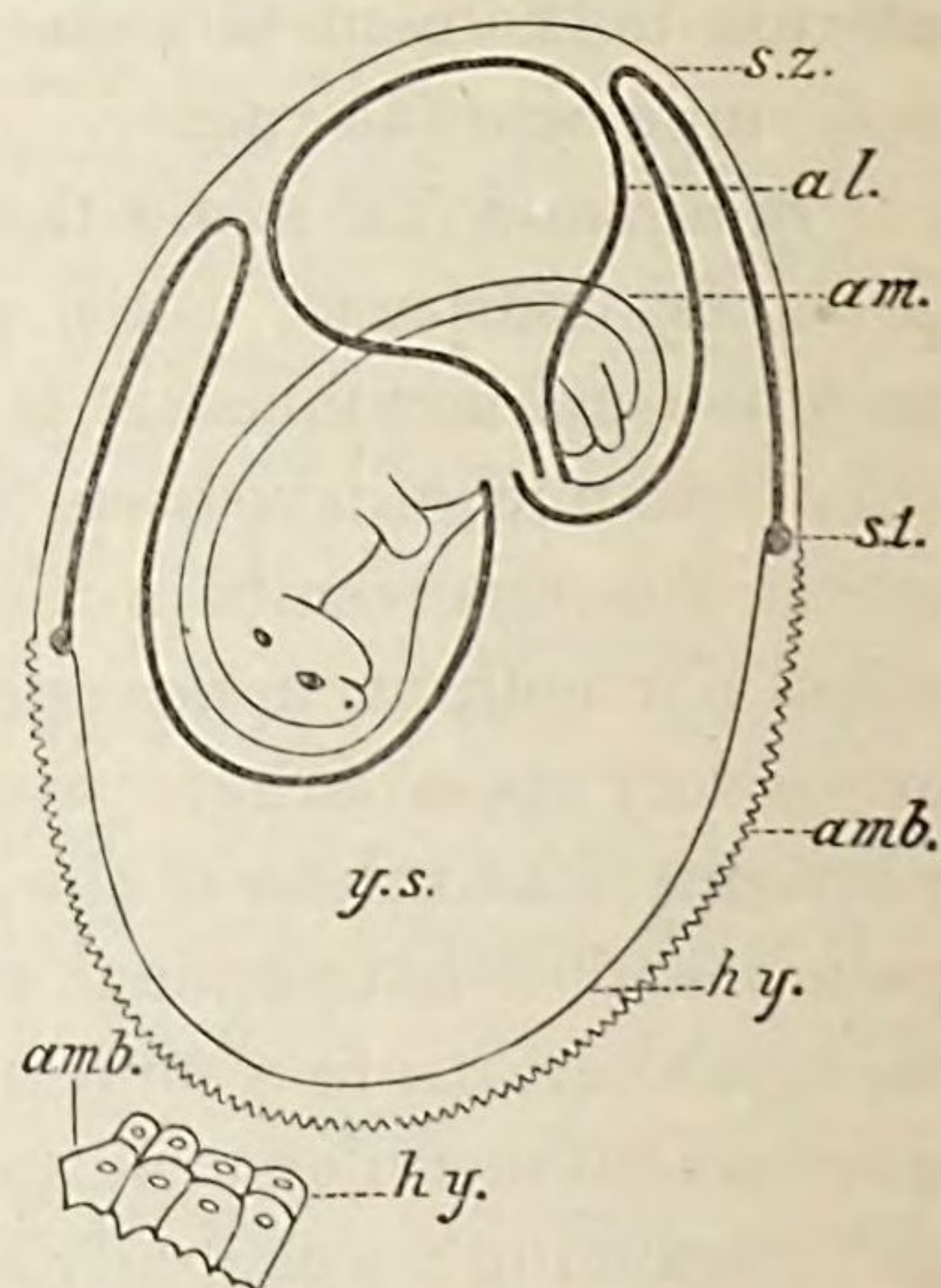


Fig. 7.

Diagram of the foetal membranes of the native bear (*Phascolarctos cinereus*), also showing the amœboid processes of the (epiblastic) cells of the subzonal membrane. After Caldwell.

al. allantois; am. amnion; amb. amœboid processes of subzonal membrane; h.y. hypoblast of yolk-sac; s. t. sinus terminalis; s. z., subzonal membrane; y. s. yolk-sac. The black line in both figures indicates the extension of the vascular system.

that portion of the subzonal membrane which is in contact with the yolk-sac, chorion of the yolk-sac, gives rise to very simple vascular villi, by means of which the embryo is slightly attached to the uterine wall (fig. 6). Caldwell (7) found that in *Phascolarctos cinereus*

and *Halmaturus ruficollis* the cells of the subzonal membrane overlying the yolk-sac outside the sinus terminalis become amoeboid, and throw out pseudopodia-like processes which fit in between the cells of the uterine epithelium and serve to attach the blastodermic vesicle to the uterus (fig. 7). This attachment is entirely non-vascular, and is the sole means by which the vesicle is attached to the uterus, no villi being formed.

From the nature of the case no adhesion occurs between the embryo and the parent in the Prototheria. In the Metatheria a very slight connexion does occur, but in this the yolk-sac alone takes part. As the latter was the sole nutritive organ of the earlier mammals, it would but slowly part with this function. Ryder (19) has suggested that the degeneracy of the yolk of the mammalian ovum may be due to the development of the so-called uterine milk from the uterine glands, and to have atrophied in consequence of the perfectly parasitic connexion subsisting temporarily between the maternal organism and the embryo, as was supposed by Balfour. At this stage of evolution the allantois was purely respiratory, as it is in the Sauropsida, and the yolk-sac (blastodermic vesicle) was becoming less nutritive in function.

In the Eutheria the placenta is formed by fusion of the allantois alone with the subzonal membrane, the yolk-sac becoming increasingly reduced. In the rabbit the yolk-sac spreads over a large portion of the subzonal membrane, leaving but a small area for the necessarily discoidal placenta; and, save for the non-adherence of the yolk-sac, and for the production of an allantoic placenta, a diagram of a rabbit's ovum in an advanced stage of pregnancy (*cf.* Balfour, *loc. cit.* II., fig. 148, p. 200), corresponds closely with that of Caldwell's Marsupials (fig. 7). In higher mammals the yolk-sac has a diminished and the allantois an increased extension.

Bearing the above in mind, it is very interesting to find that the first attachment of the embryo to the parent in some rodents is by the covering cells (Deckenzellen) which are later replaced by the villi of the allantoic placenta. It may be that this has relation merely to special cases; but it is probable that when our knowledge is more complete in such details it will be found that in many Eutheria there is a temporary adhesion of the walls of the blastodermic vesicle to the uterus which is subsequently supplanted by the allantoic villi.

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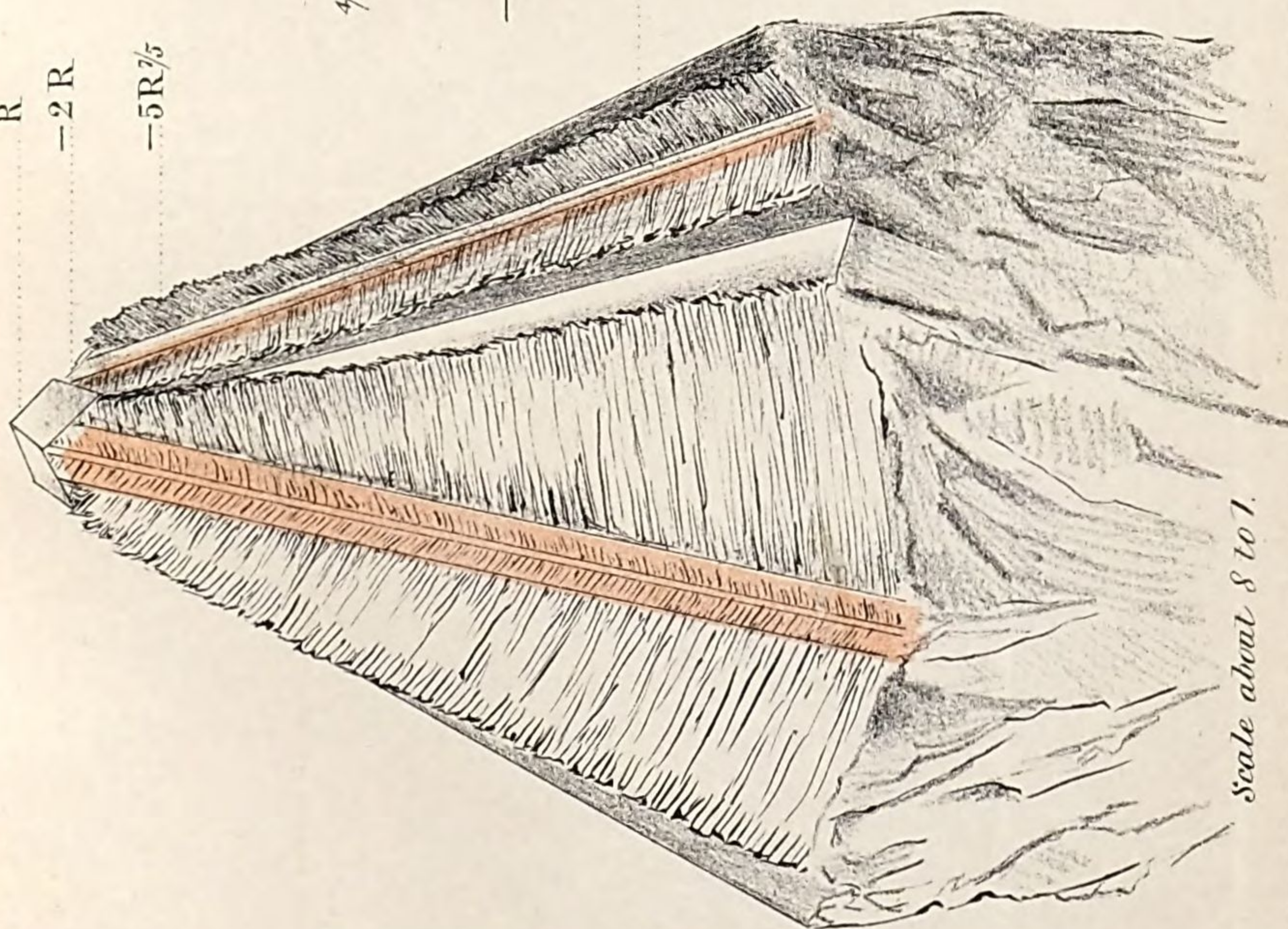
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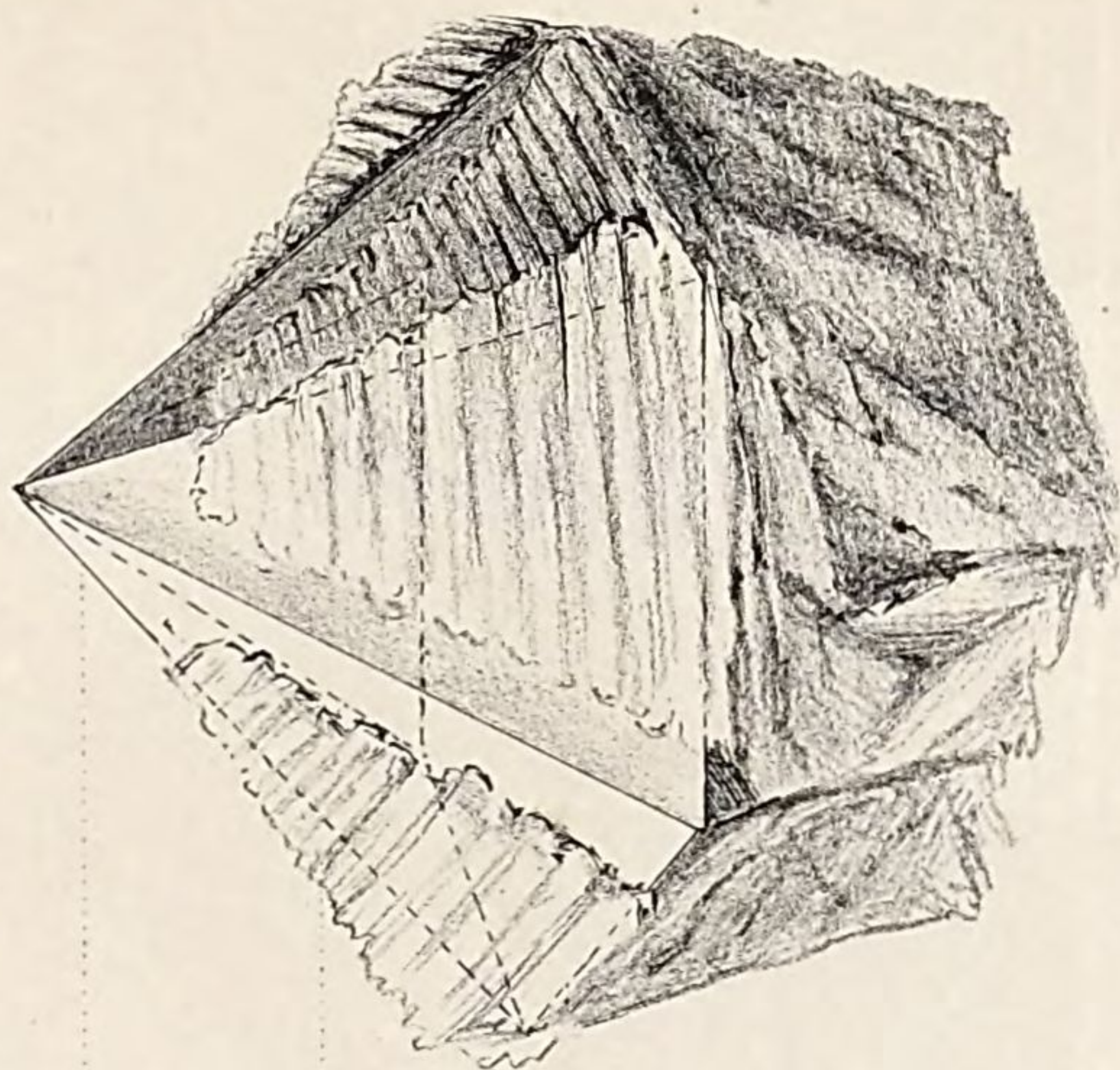
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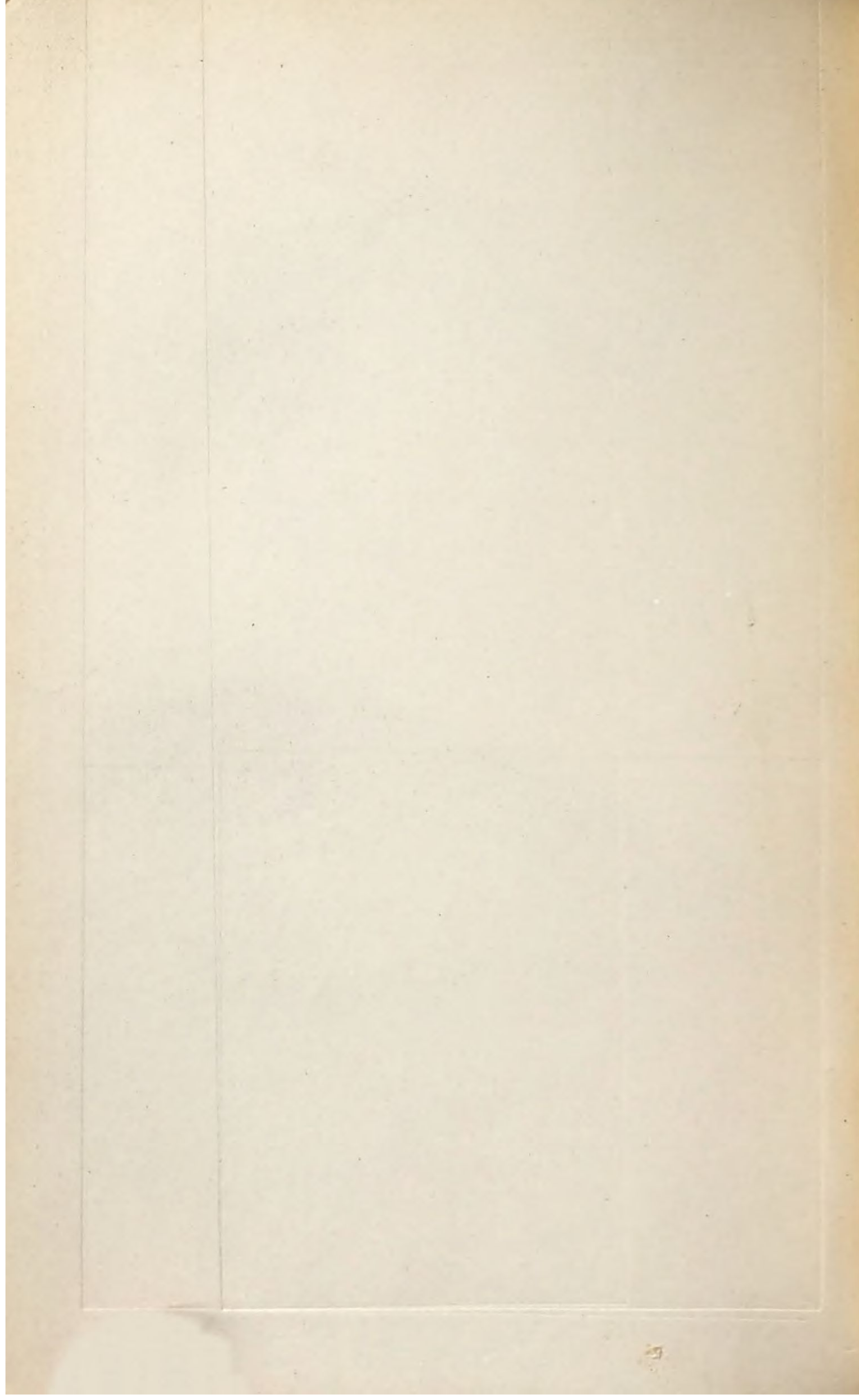


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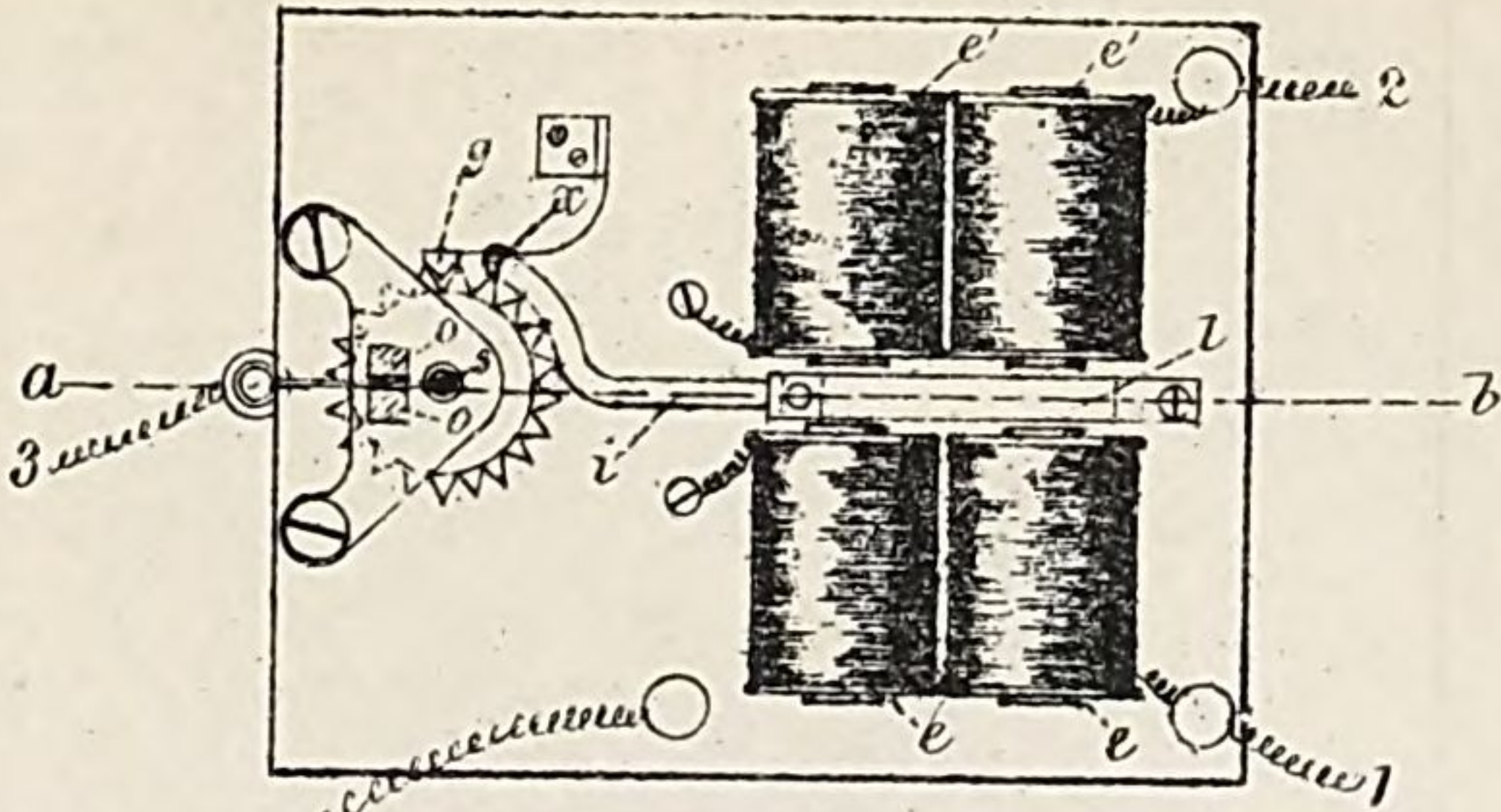
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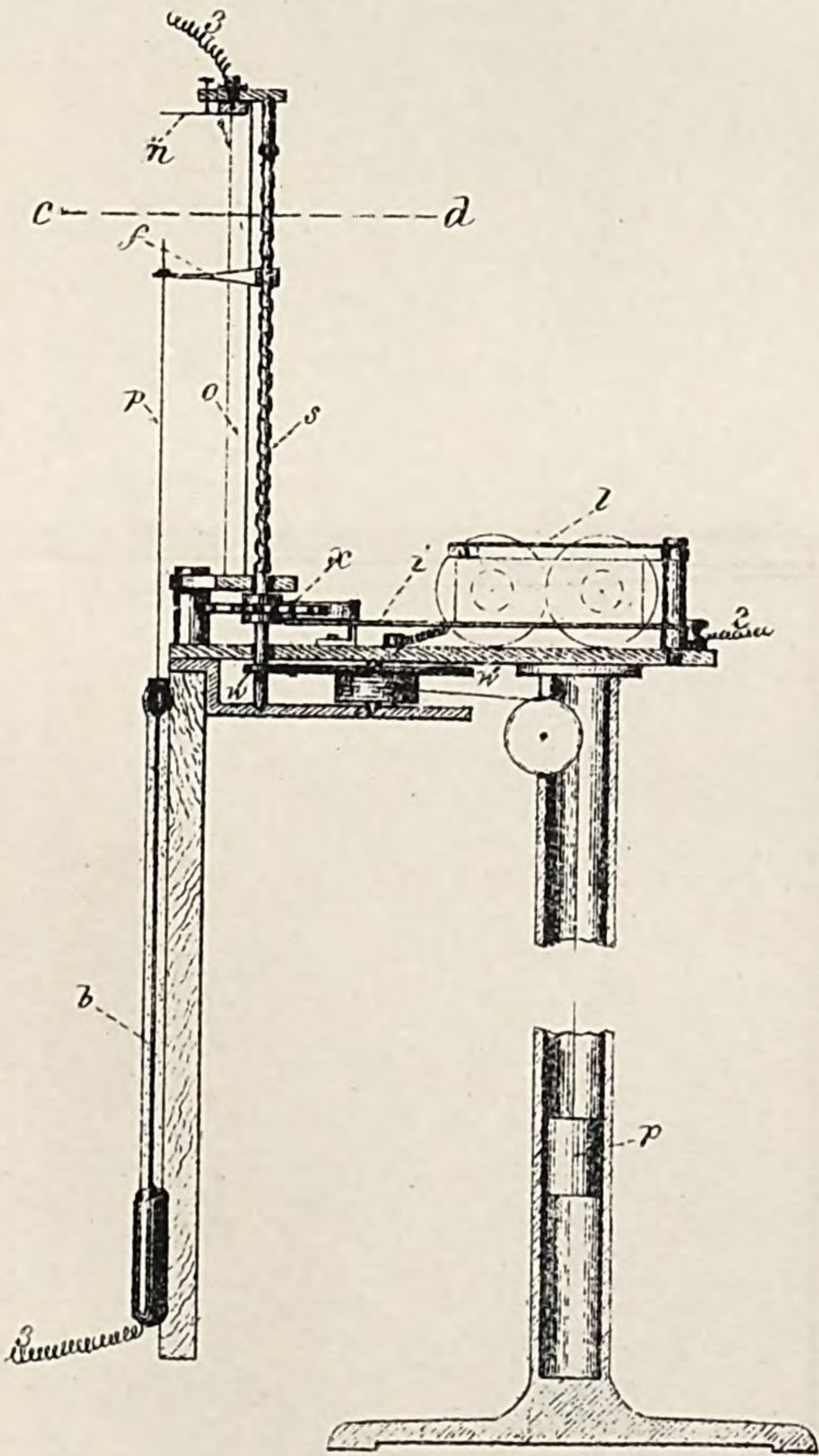
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Fig. 1.

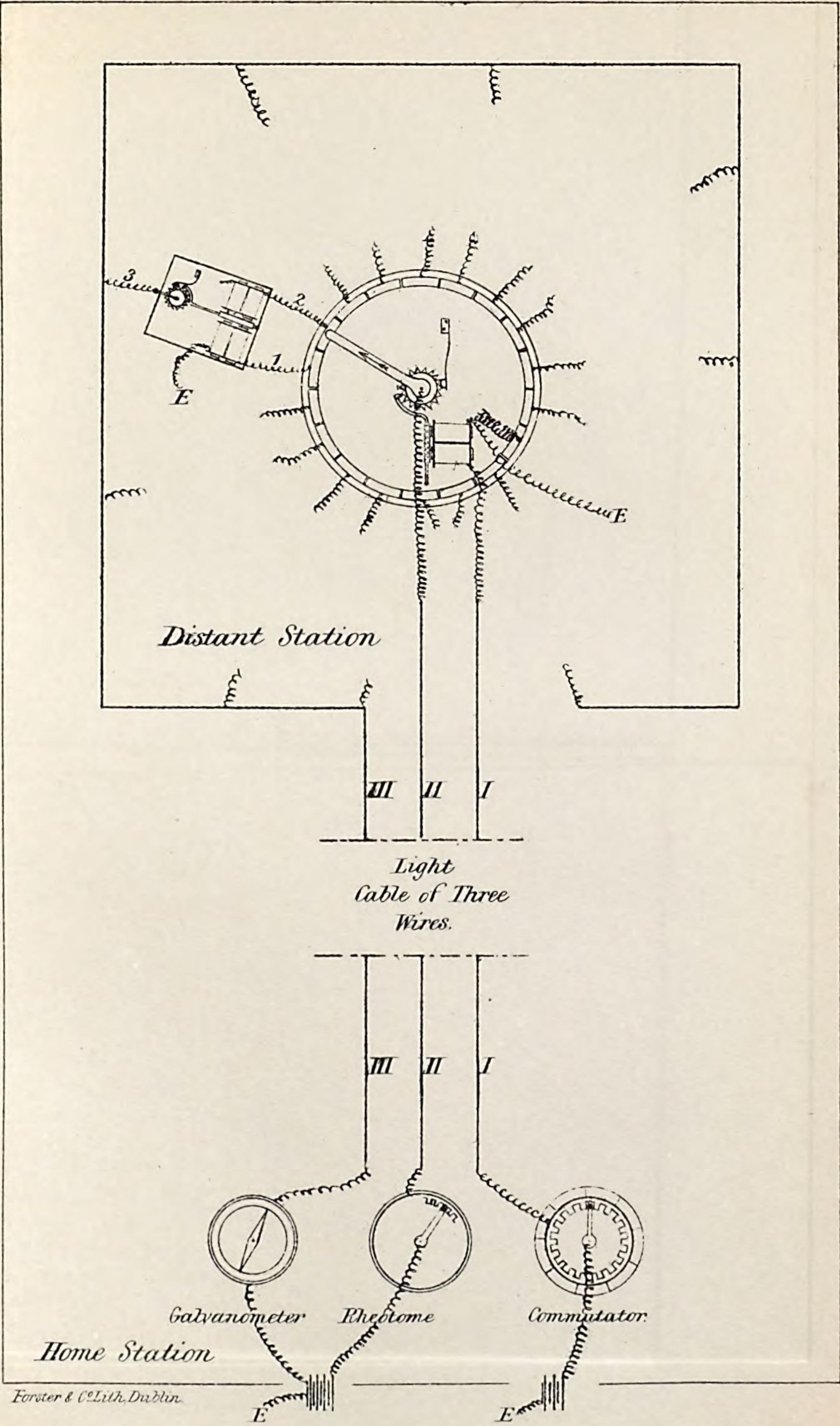


Plan-Section thro c.d. Fig. 2.

Fig. 2.



Sectional Elevation thro a.b. Fig. 1



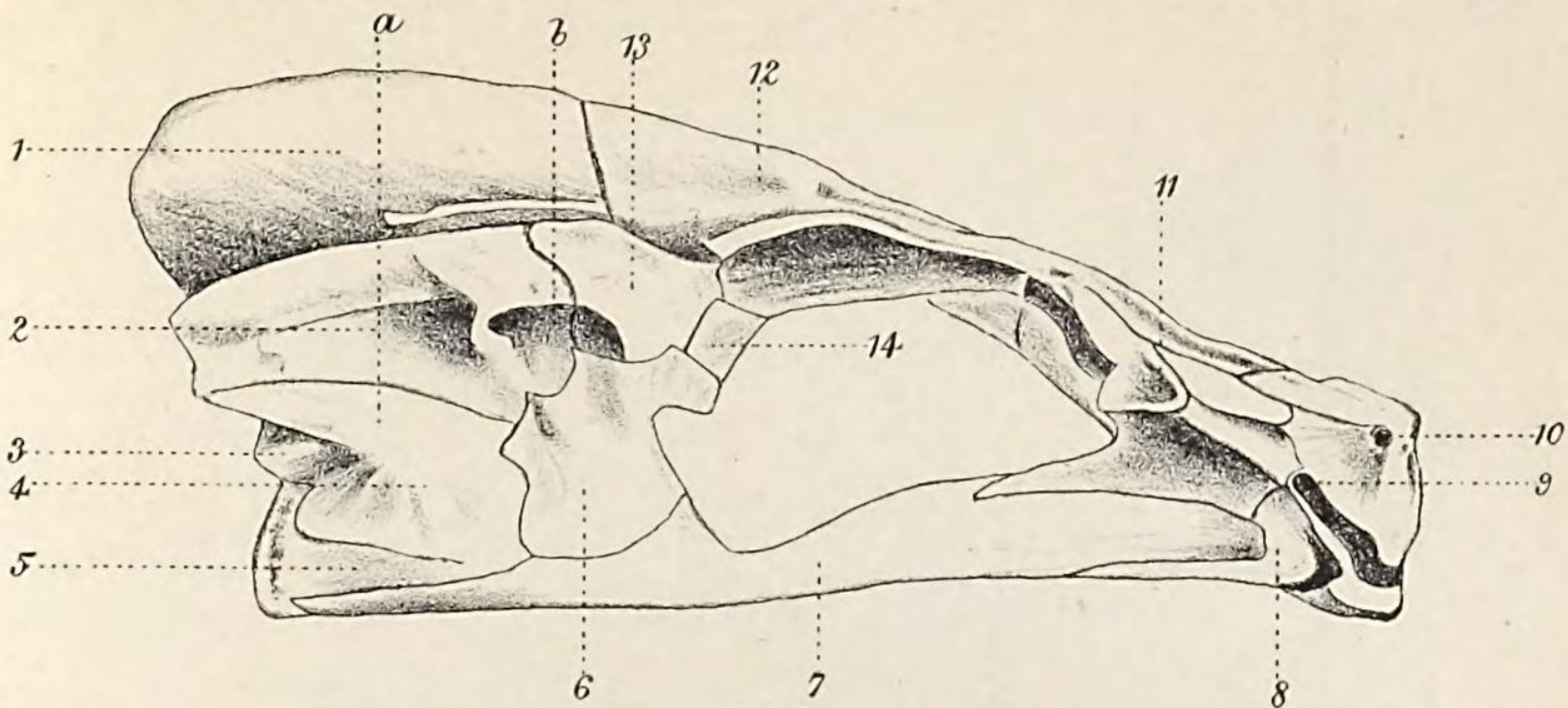


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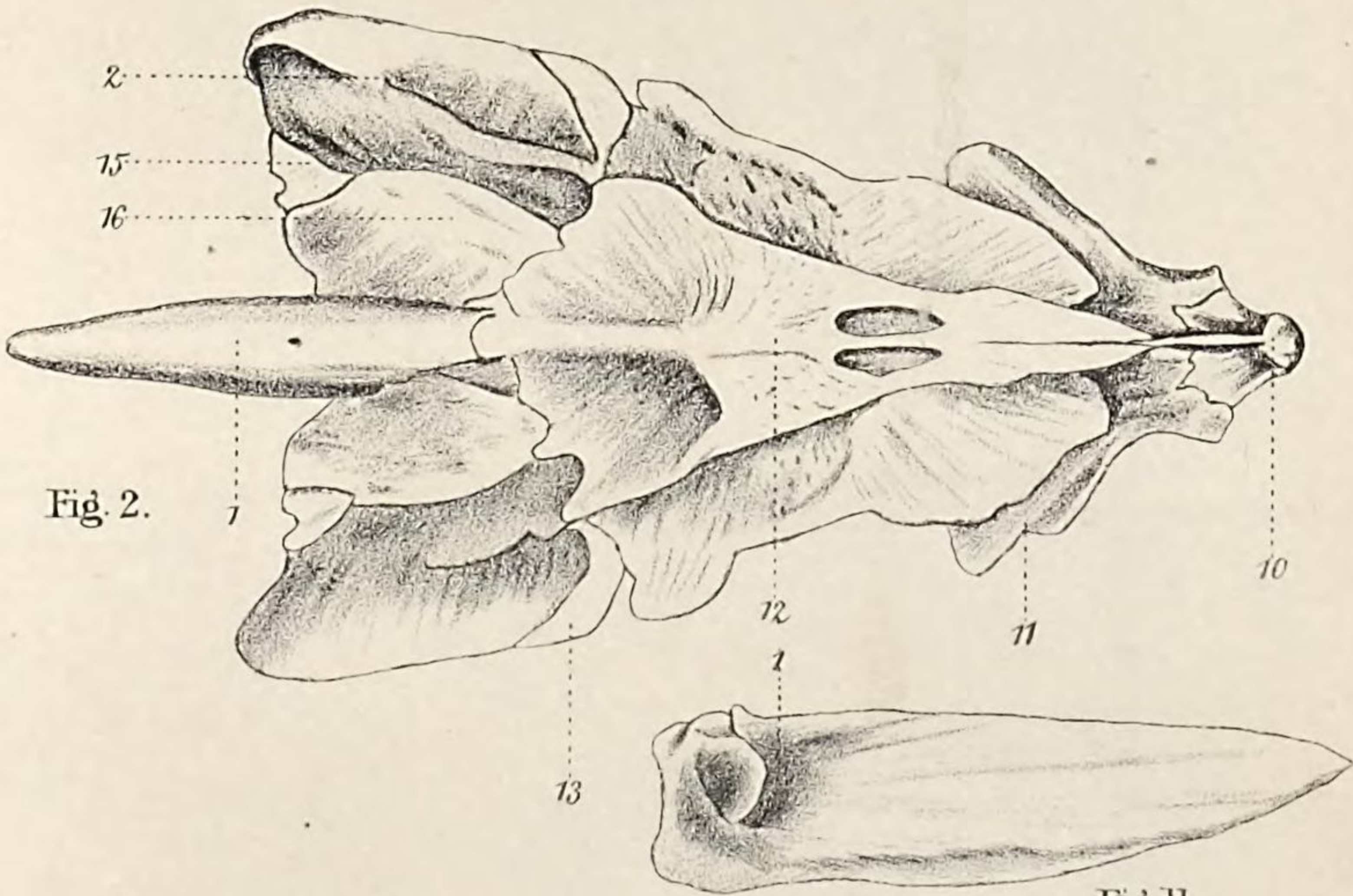


Fig. 2.



Fig. 11.

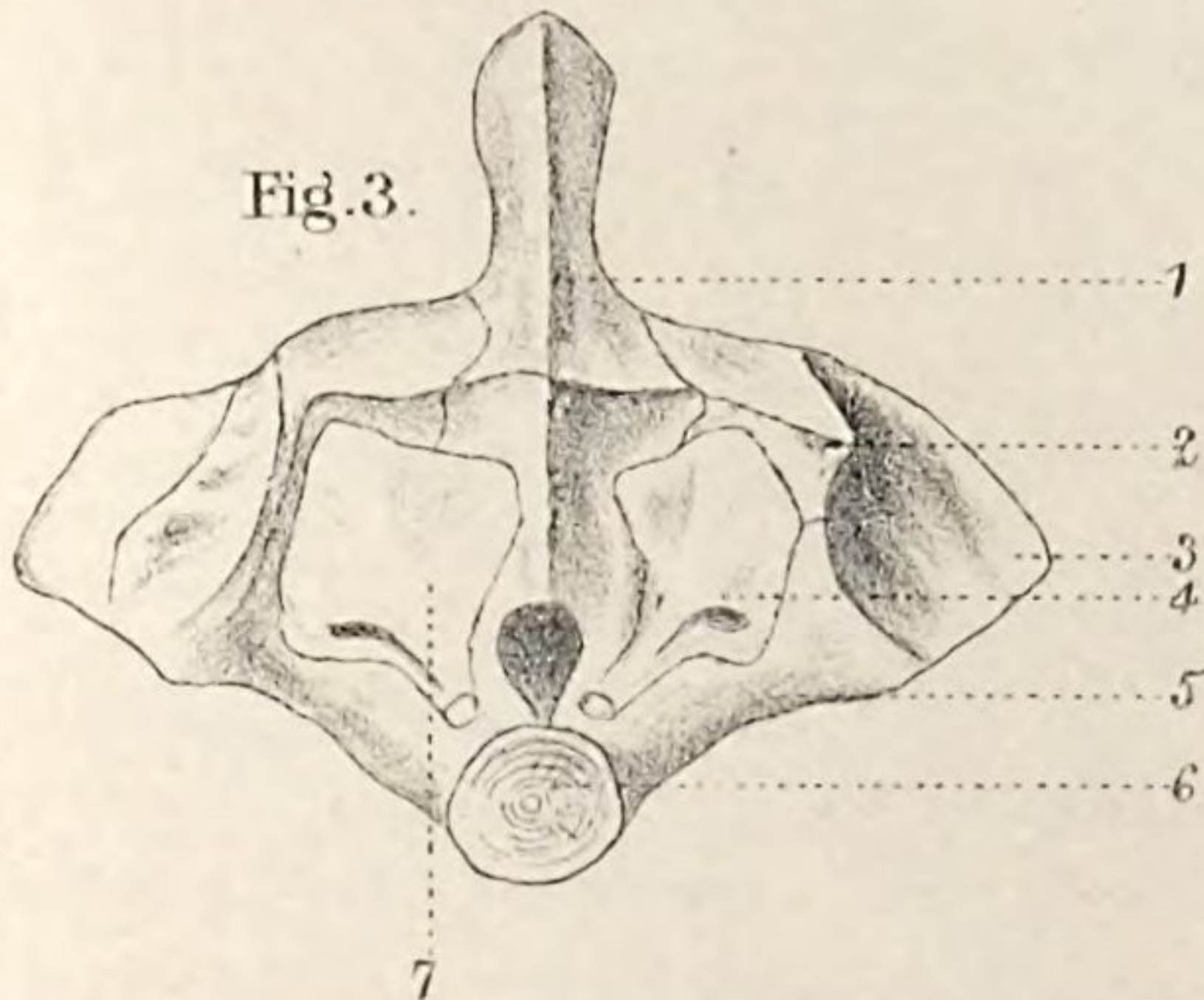


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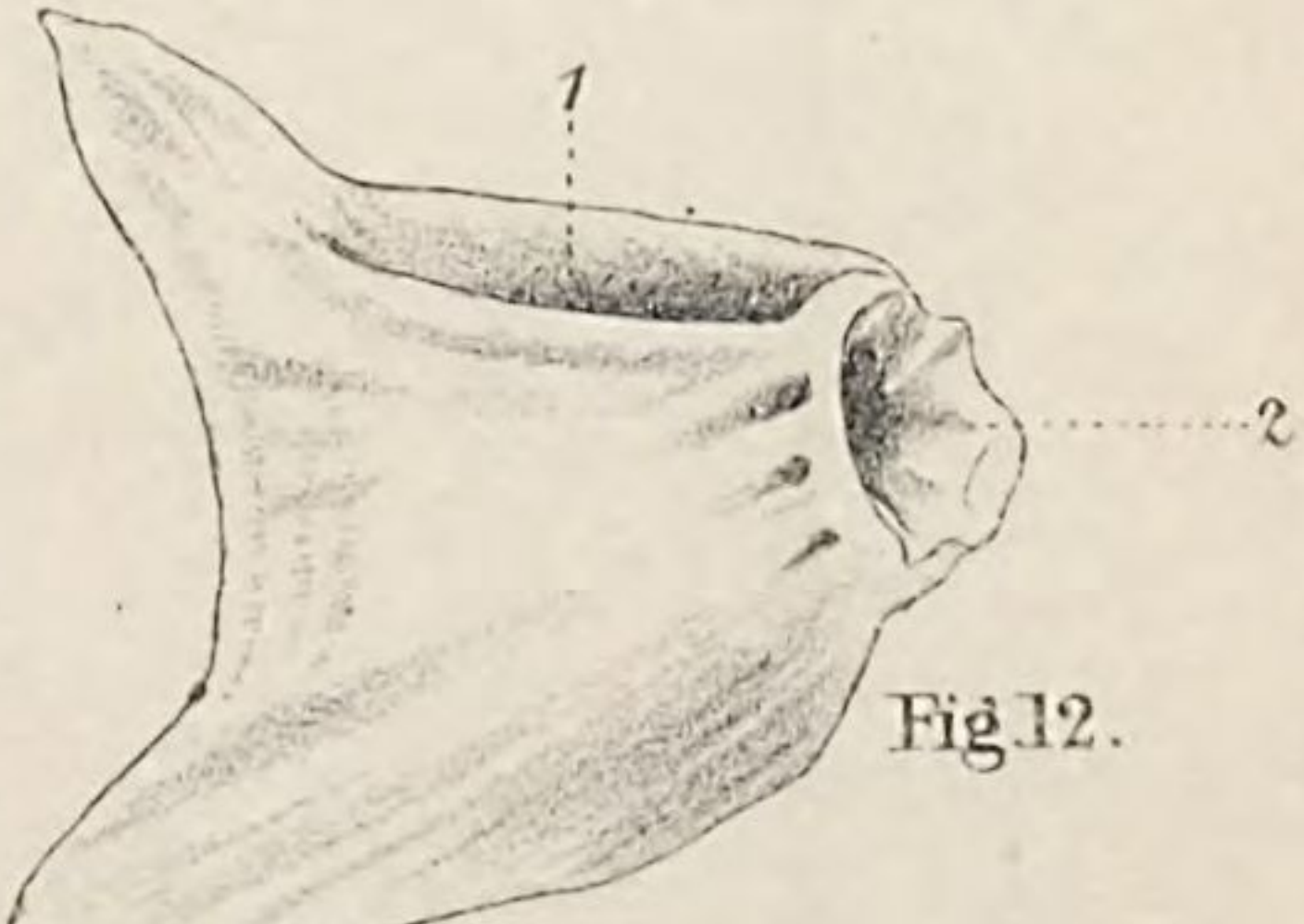
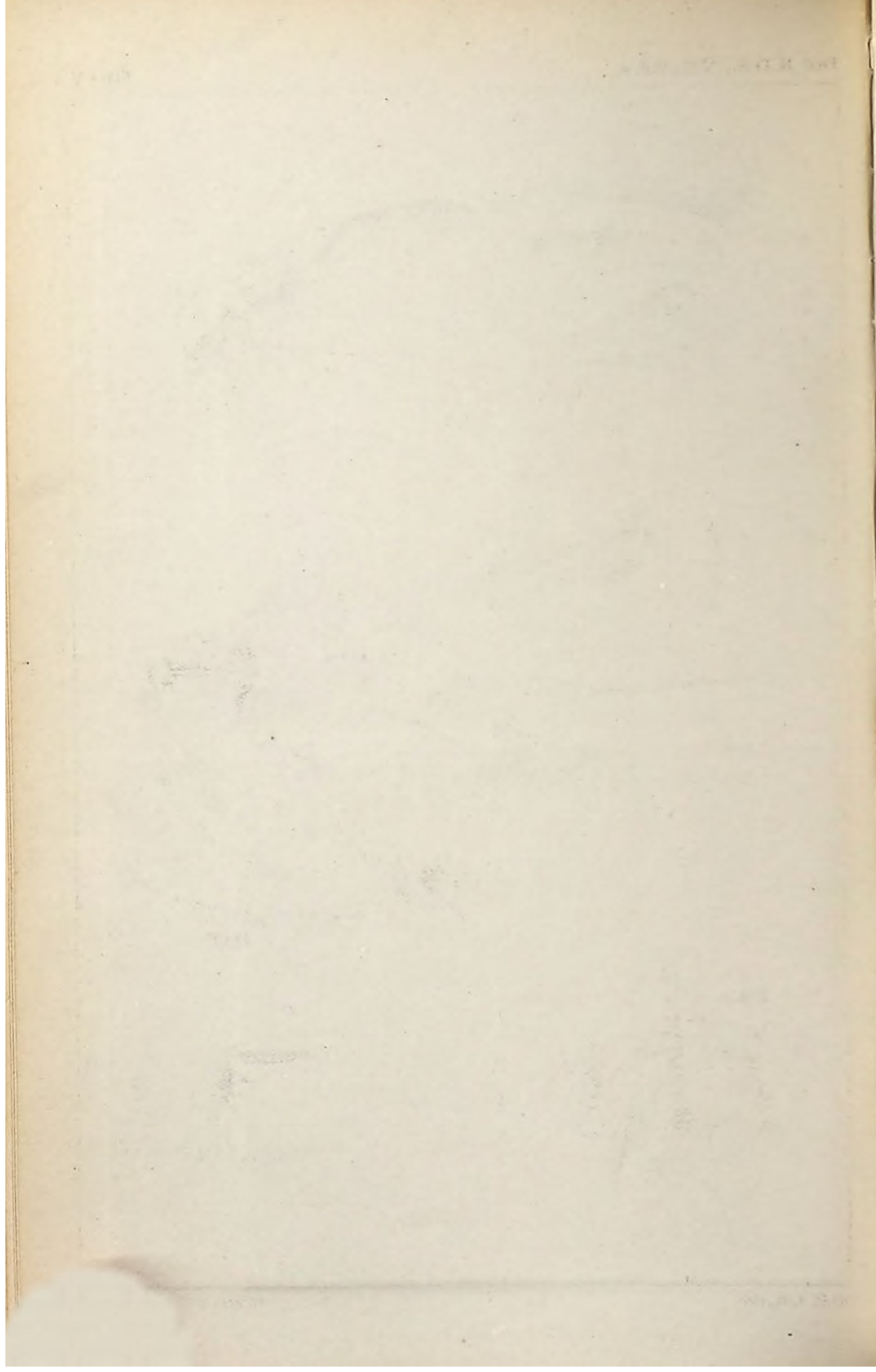
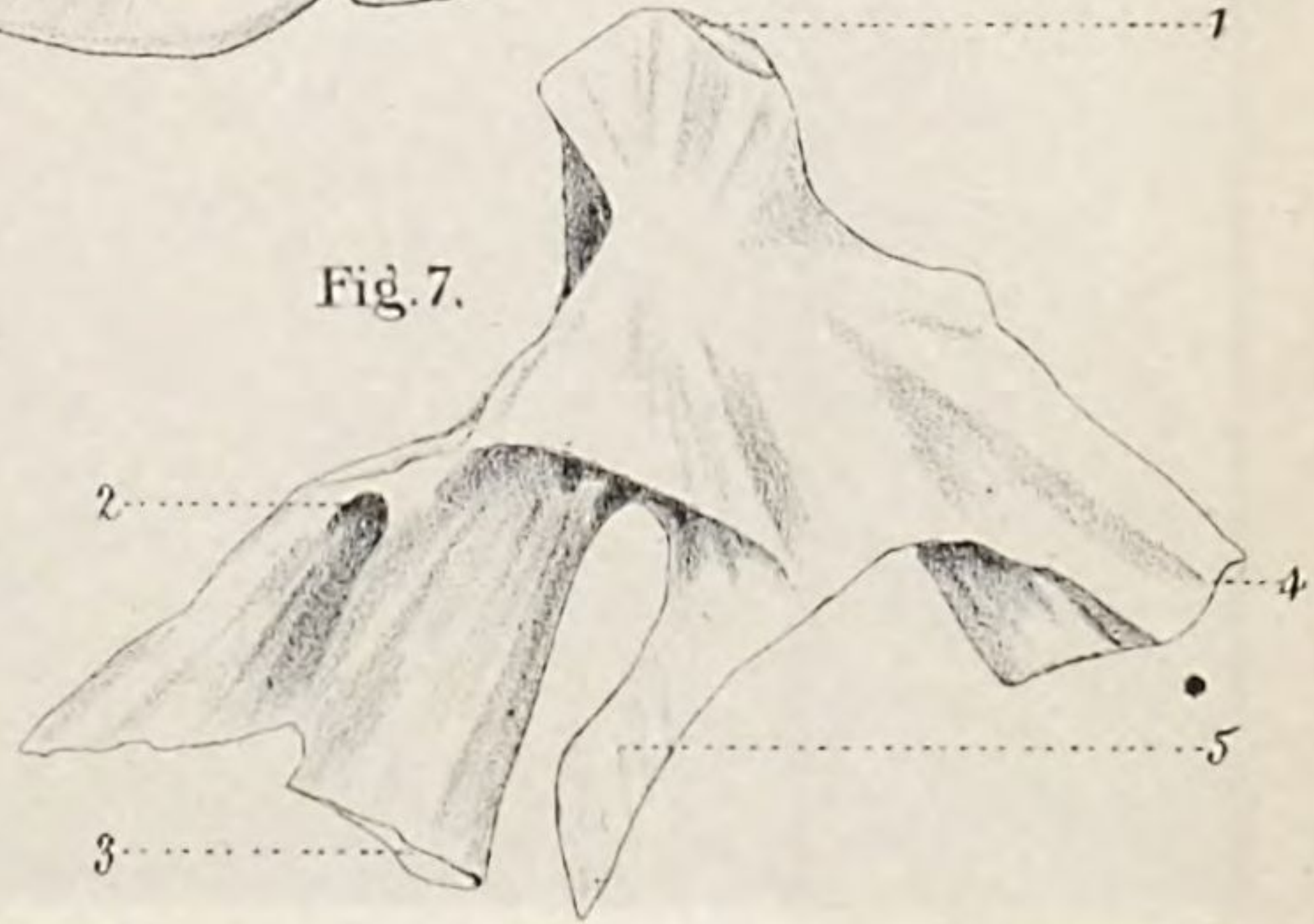
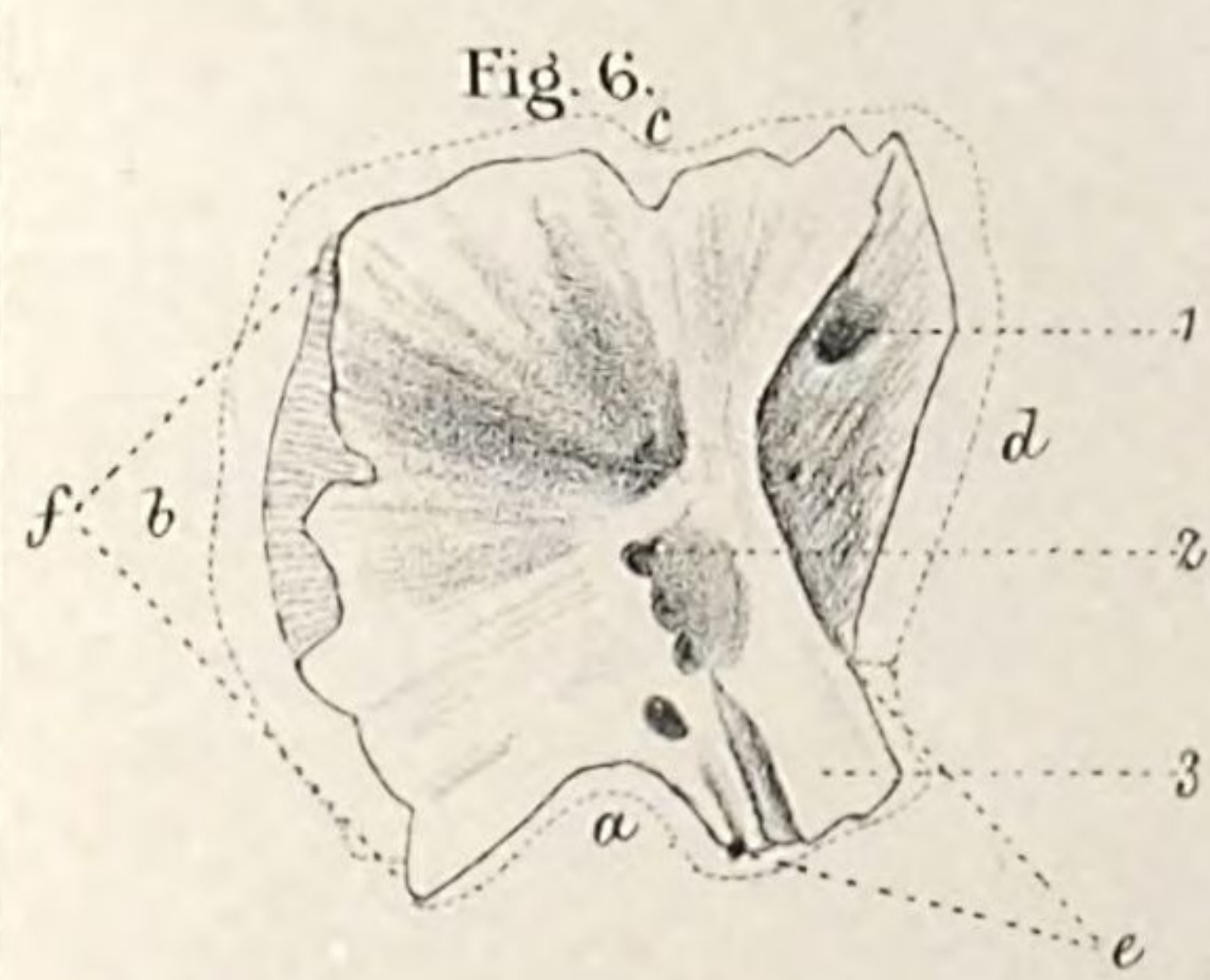
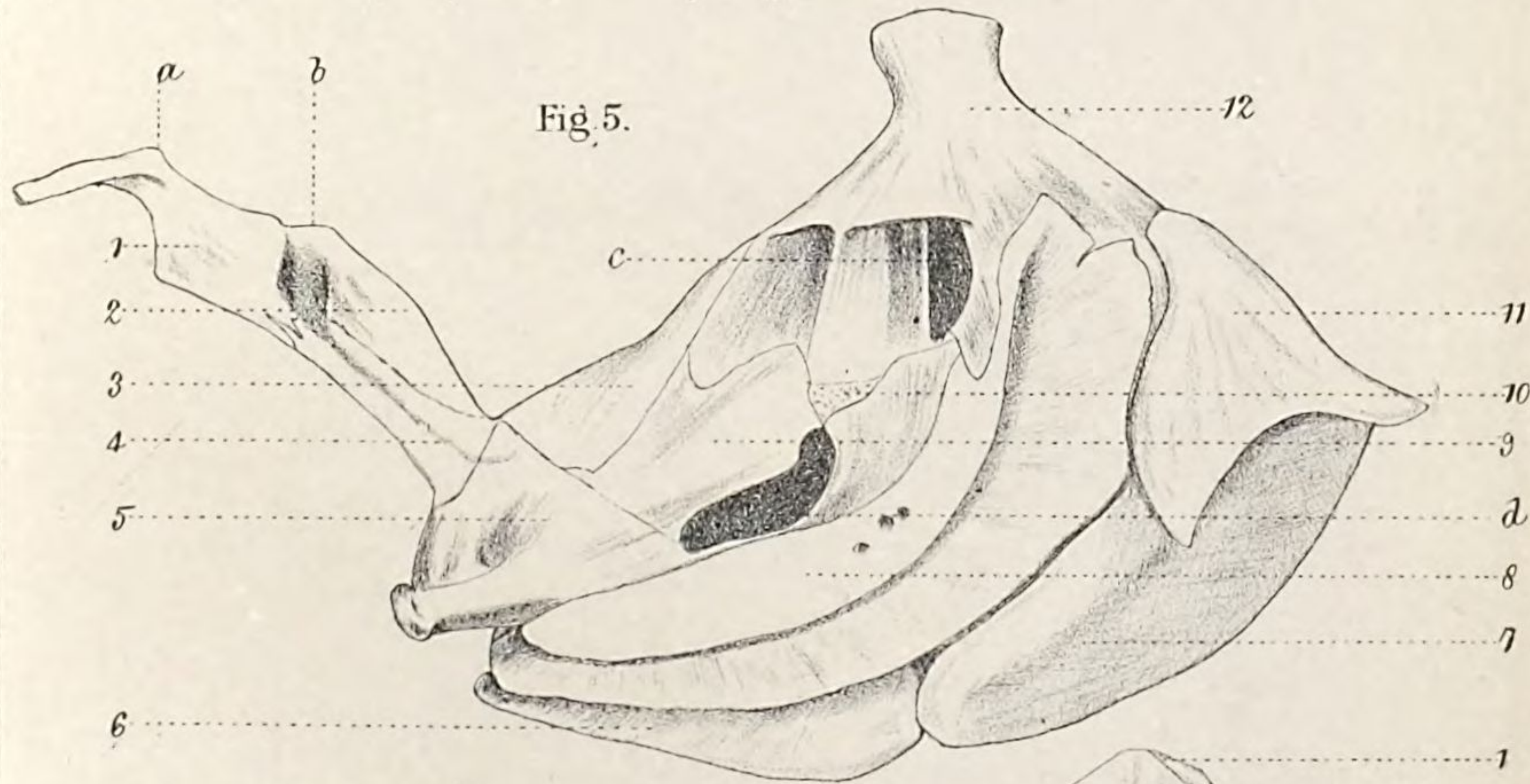
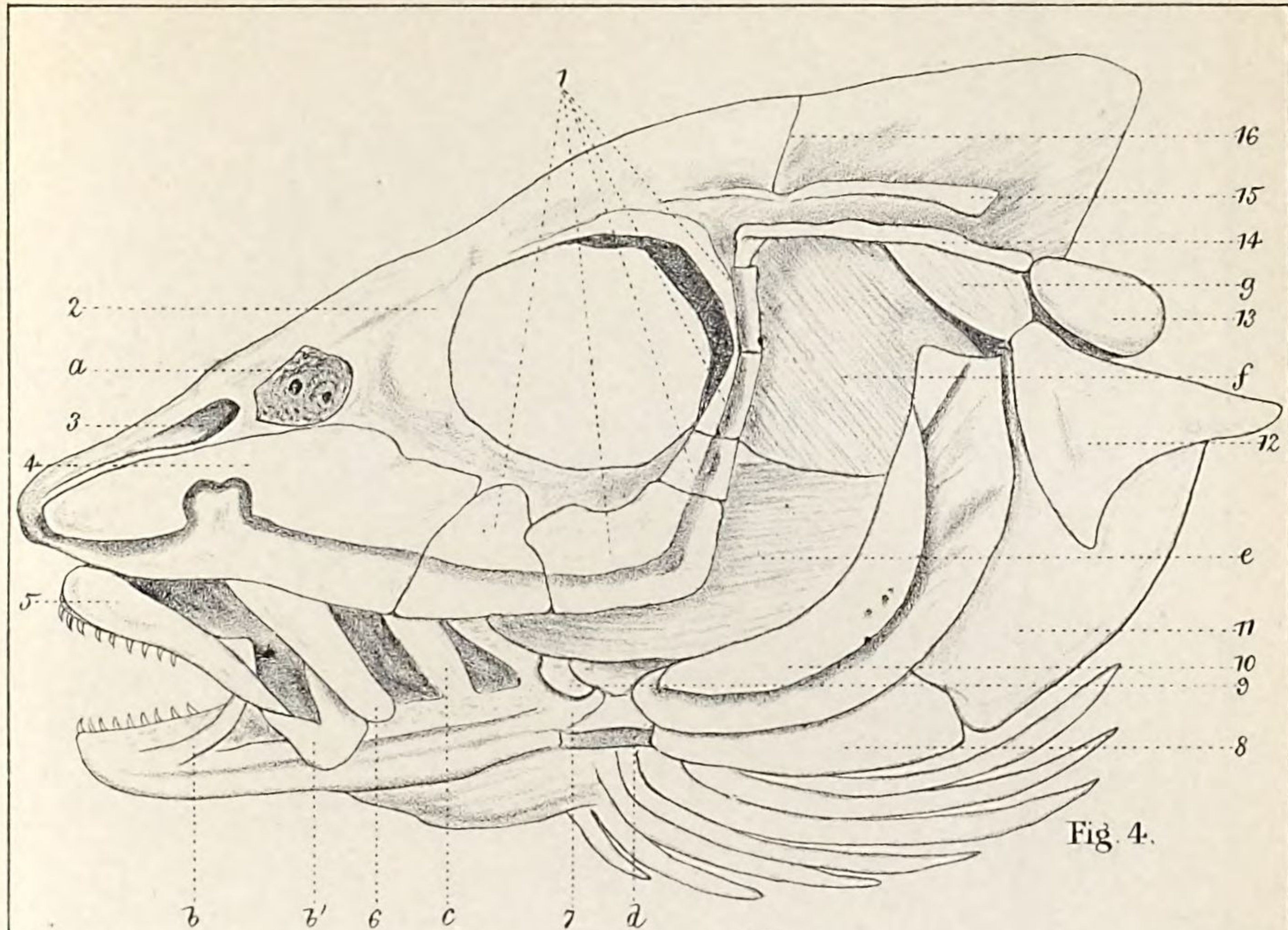
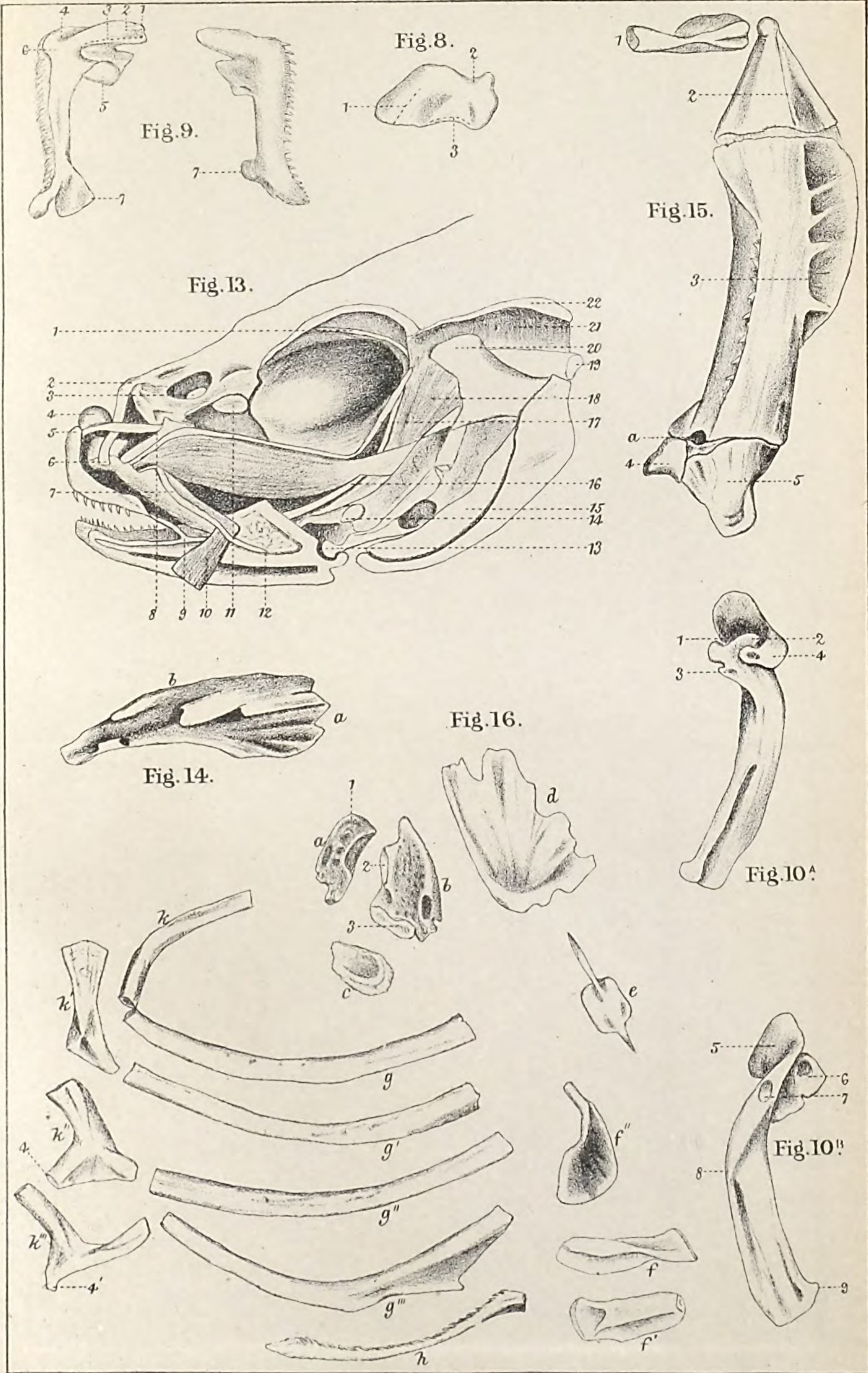


Fig. 12.







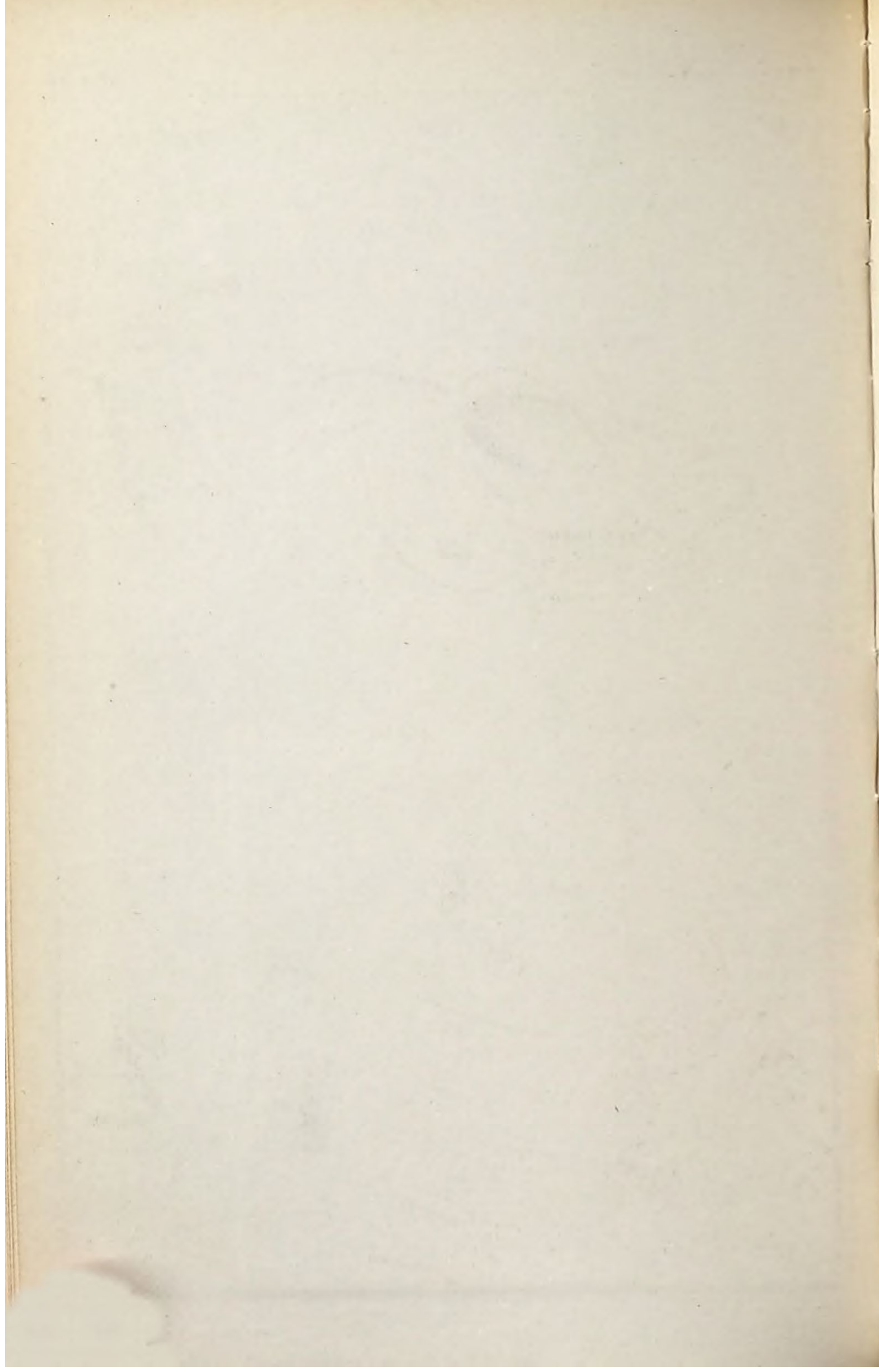


Fig. 20.



Fig. 21.

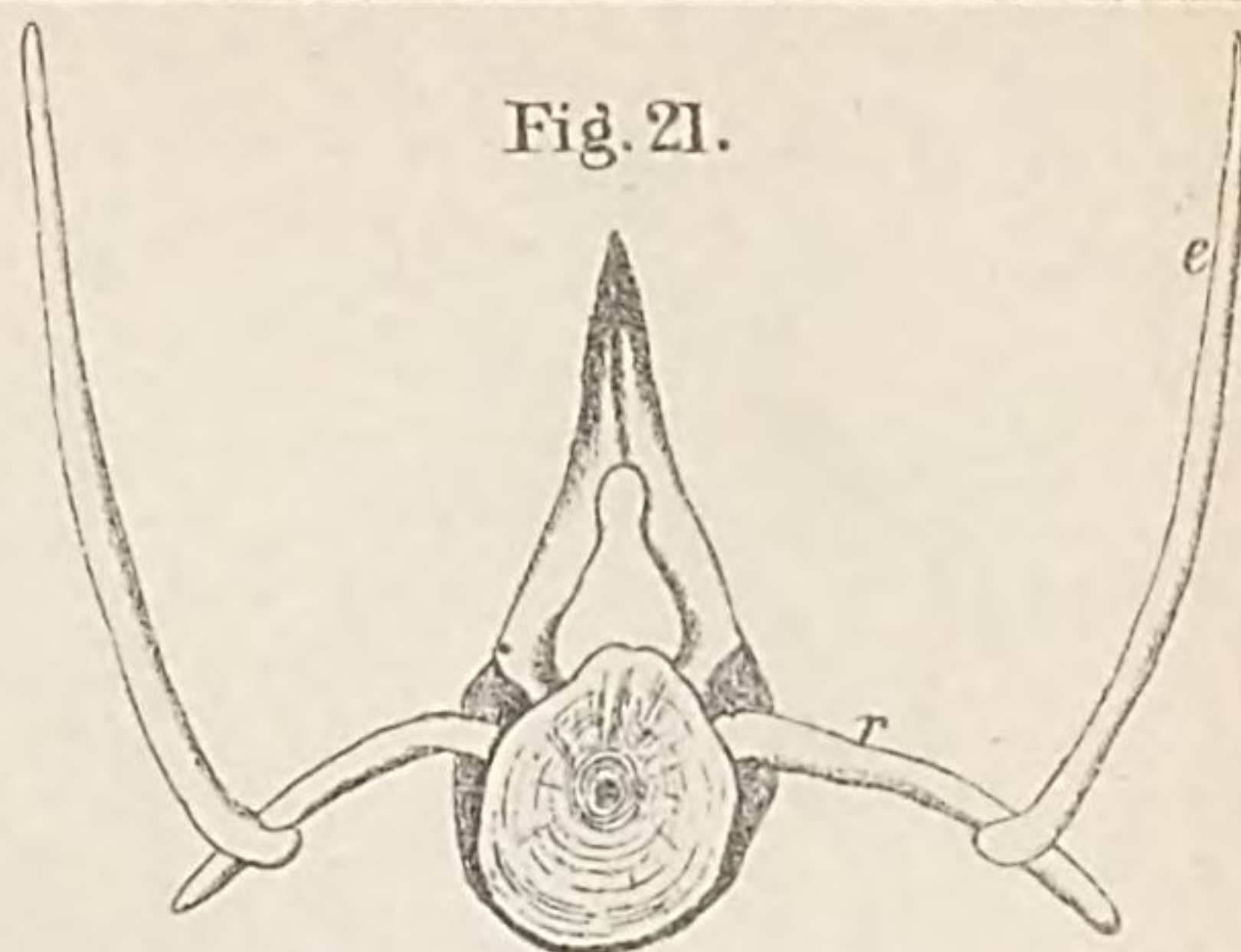


Fig. 17.

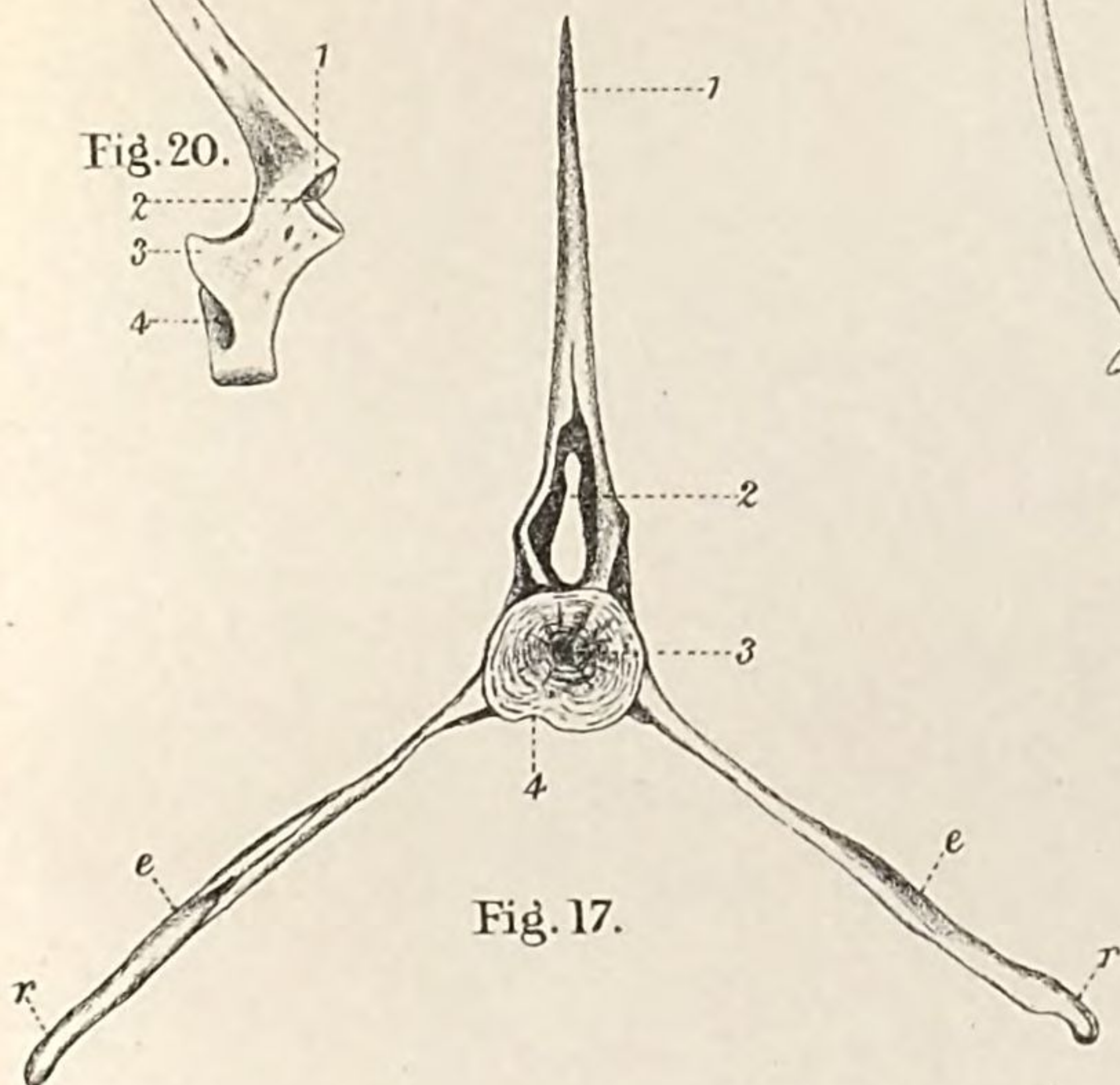


Fig. 22.

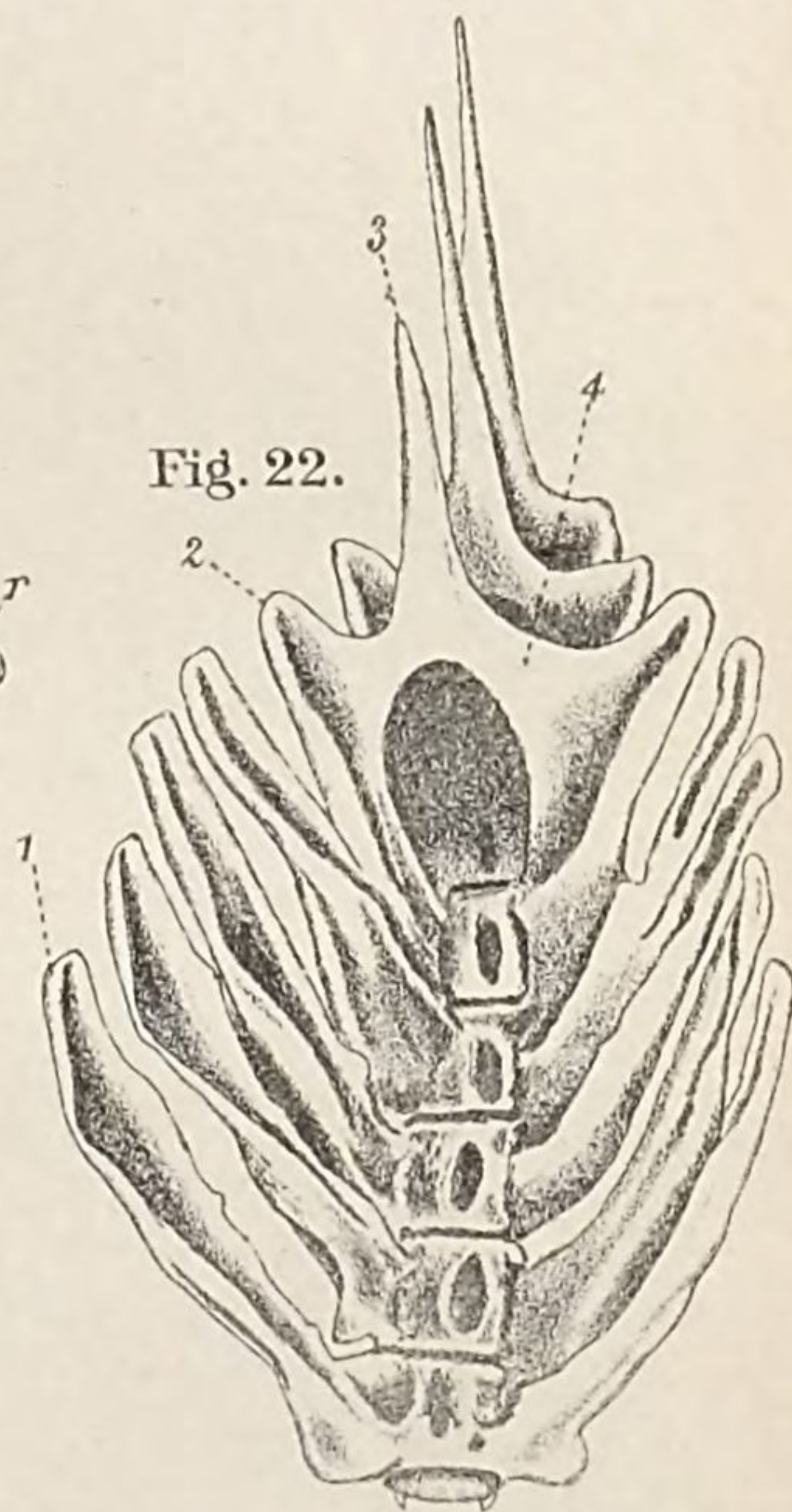


Fig. 18.

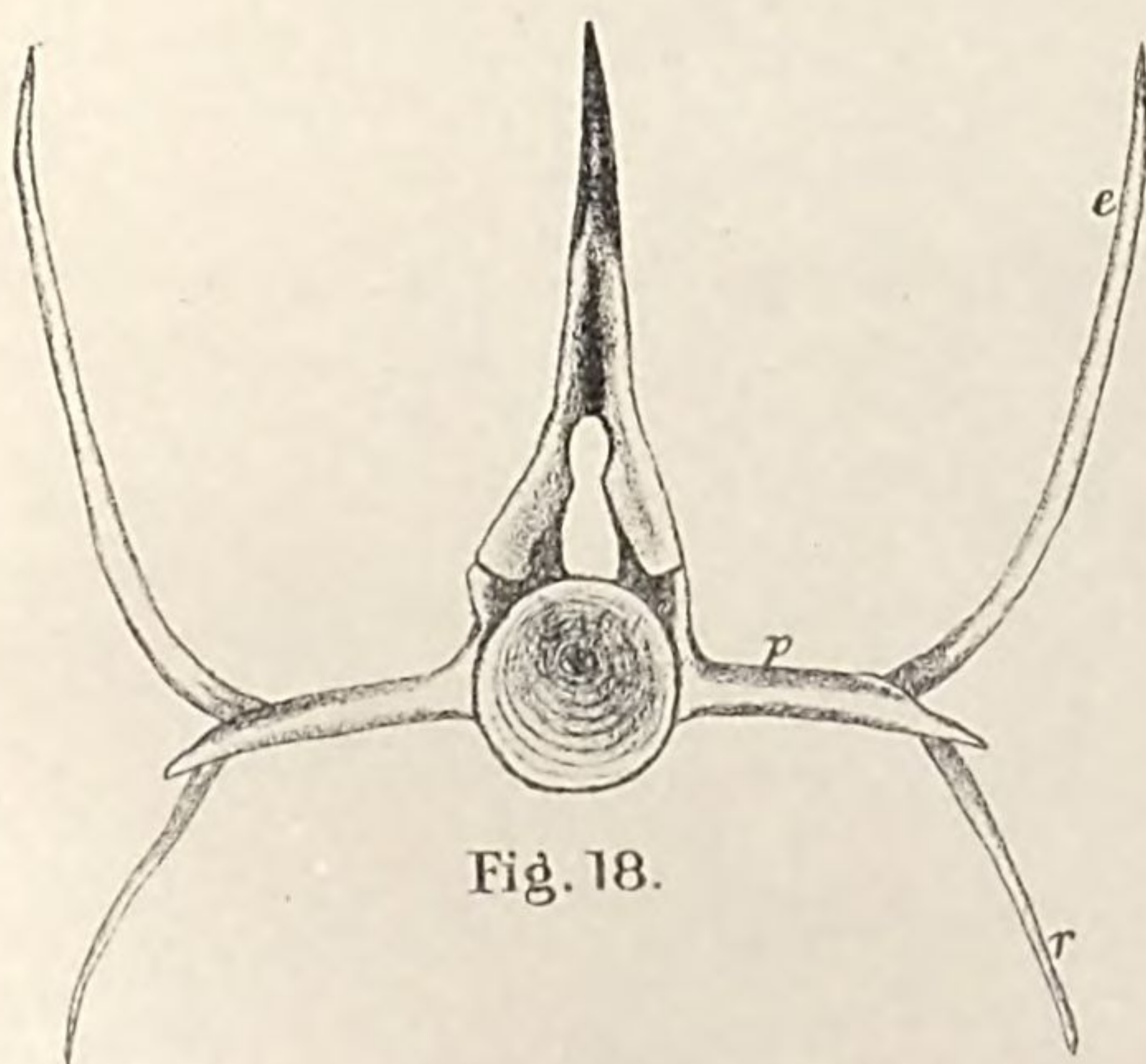


Fig. 19.

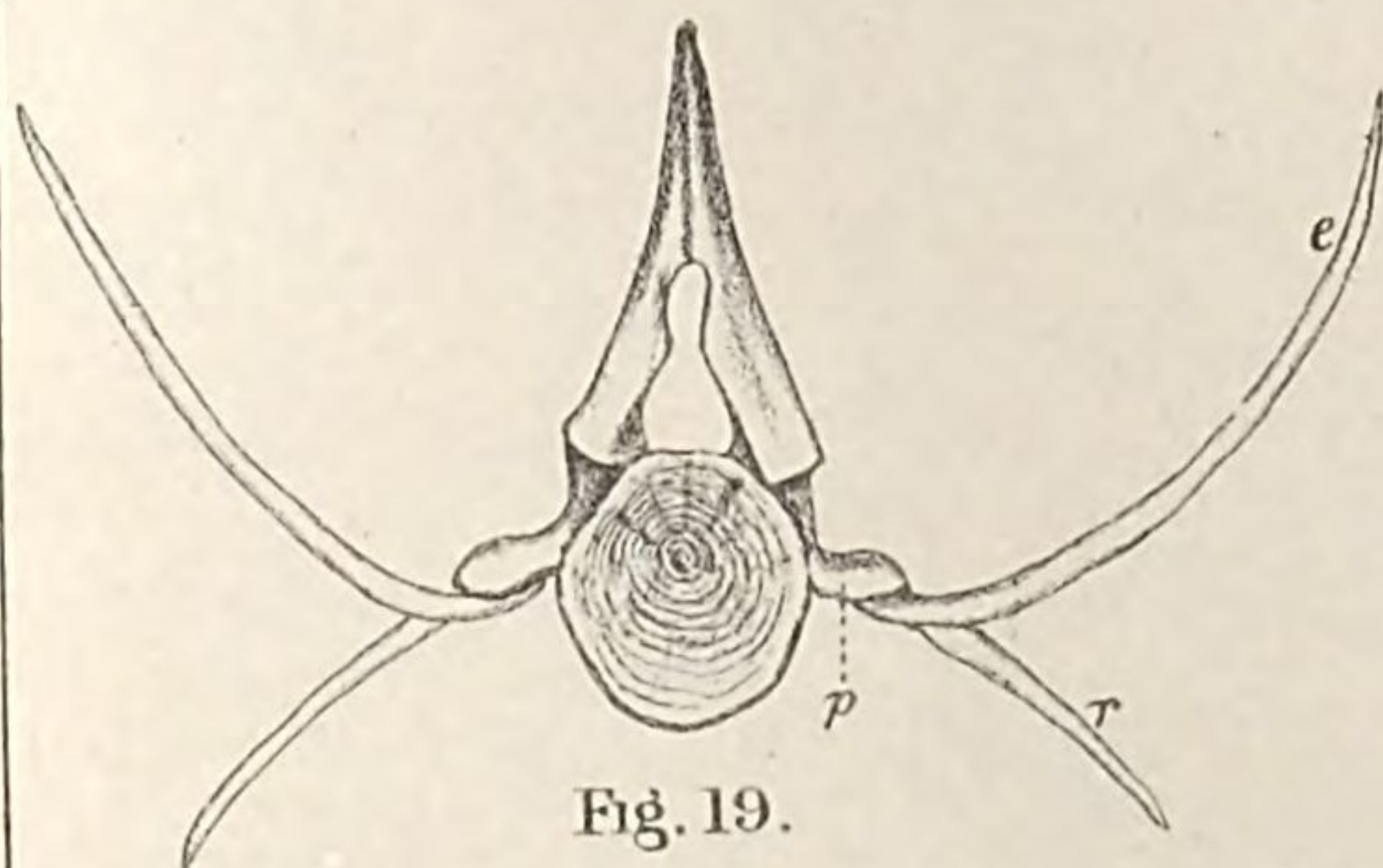
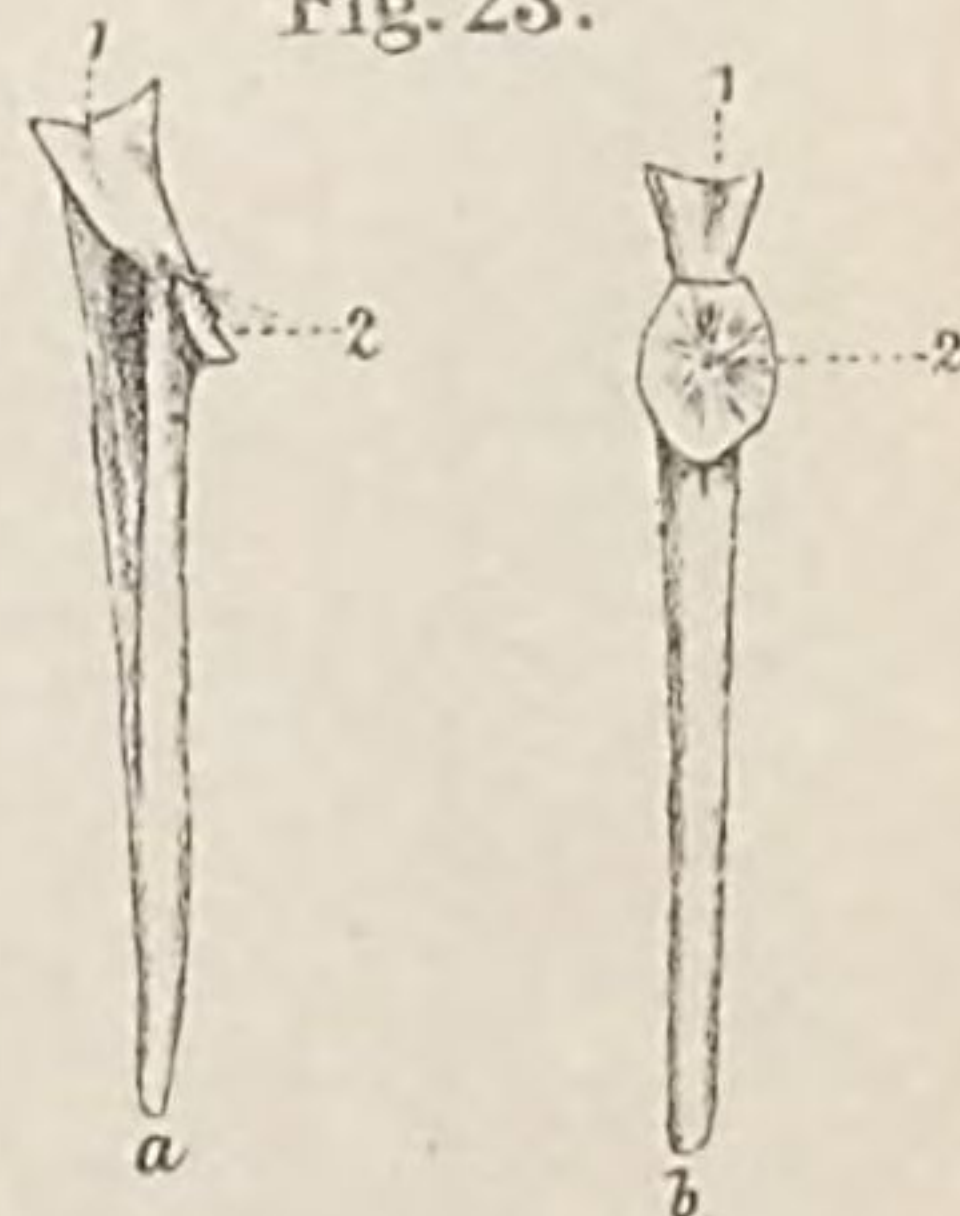


Fig. 23.



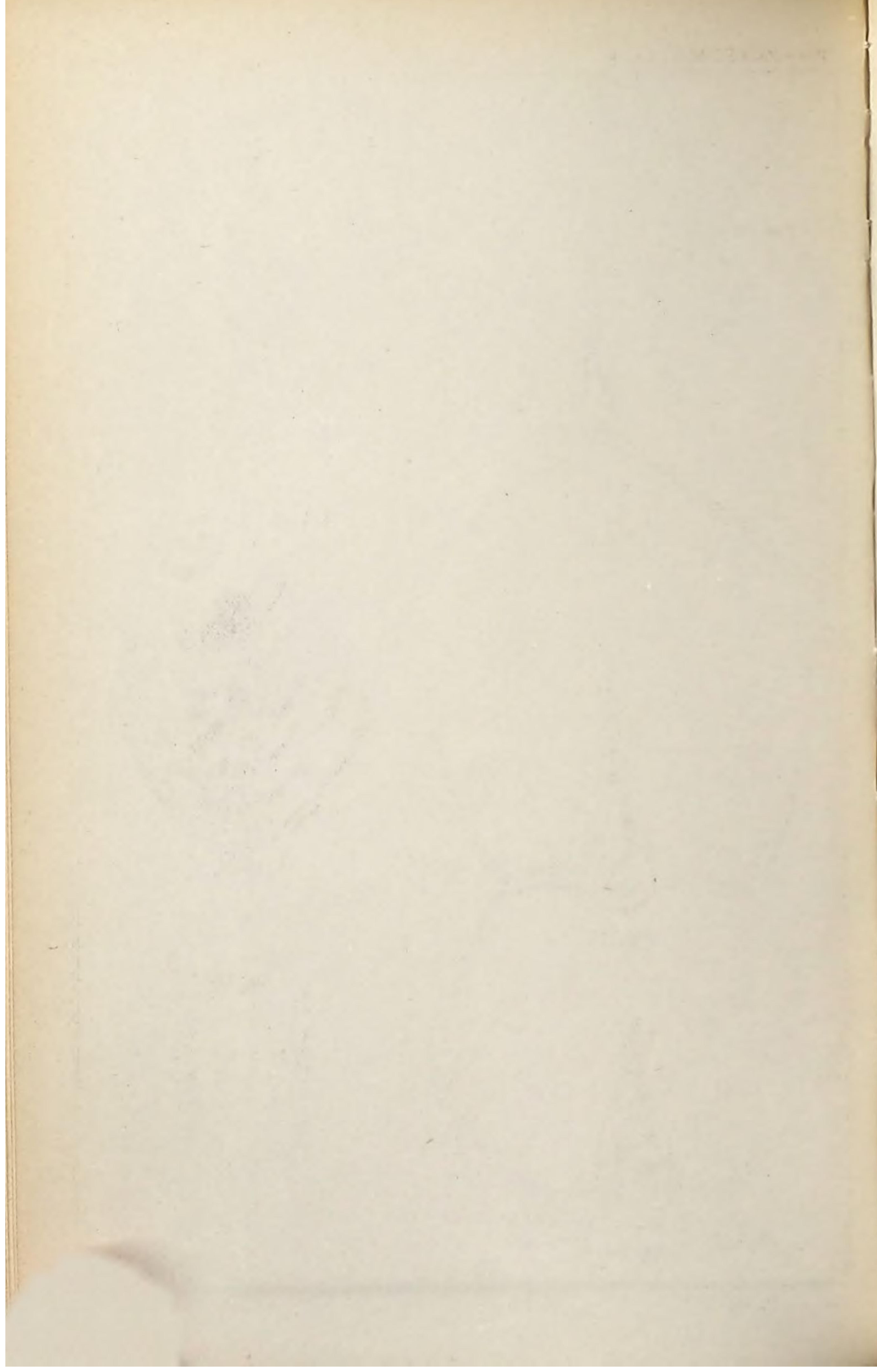


Fig. 25.

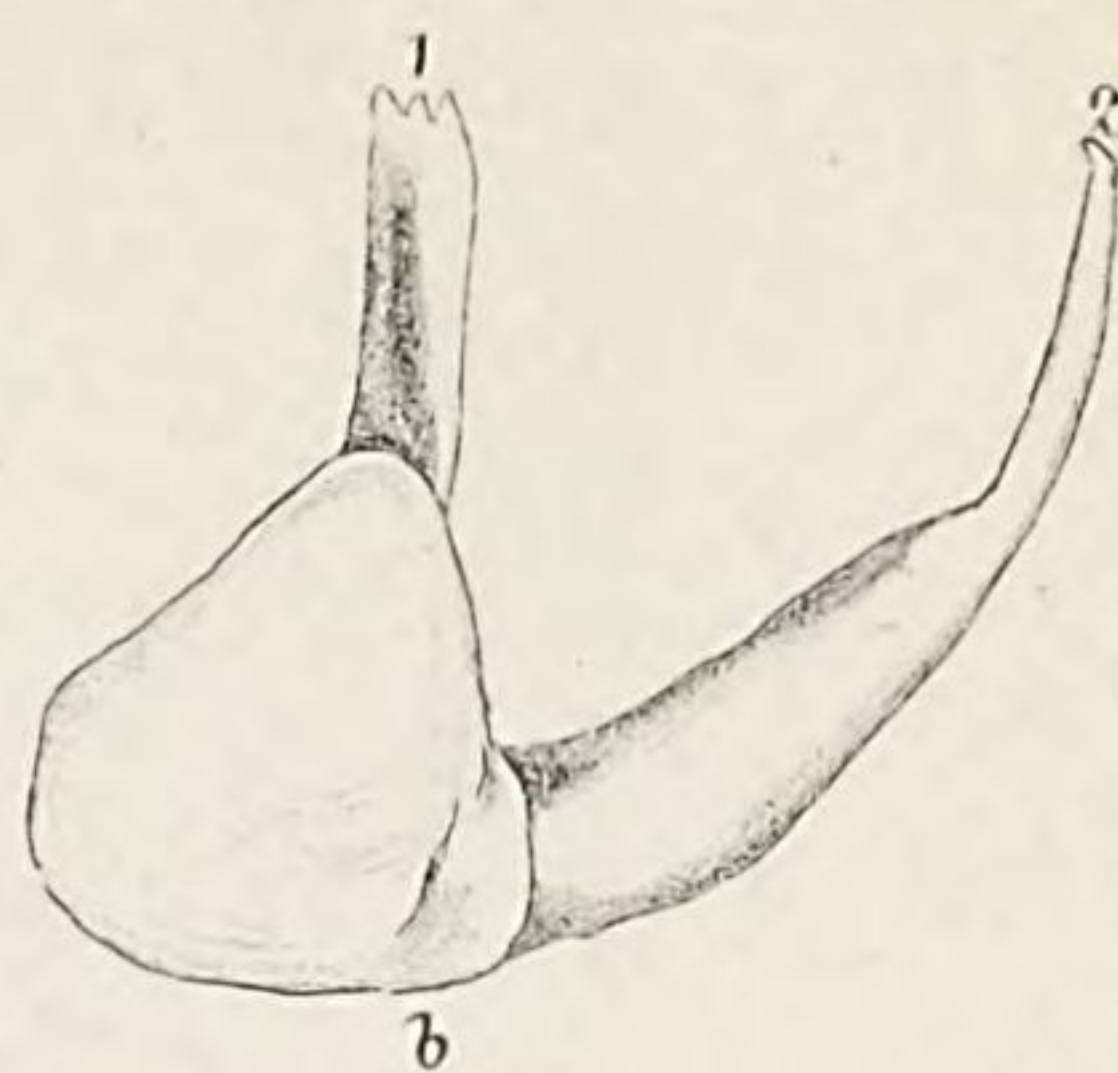
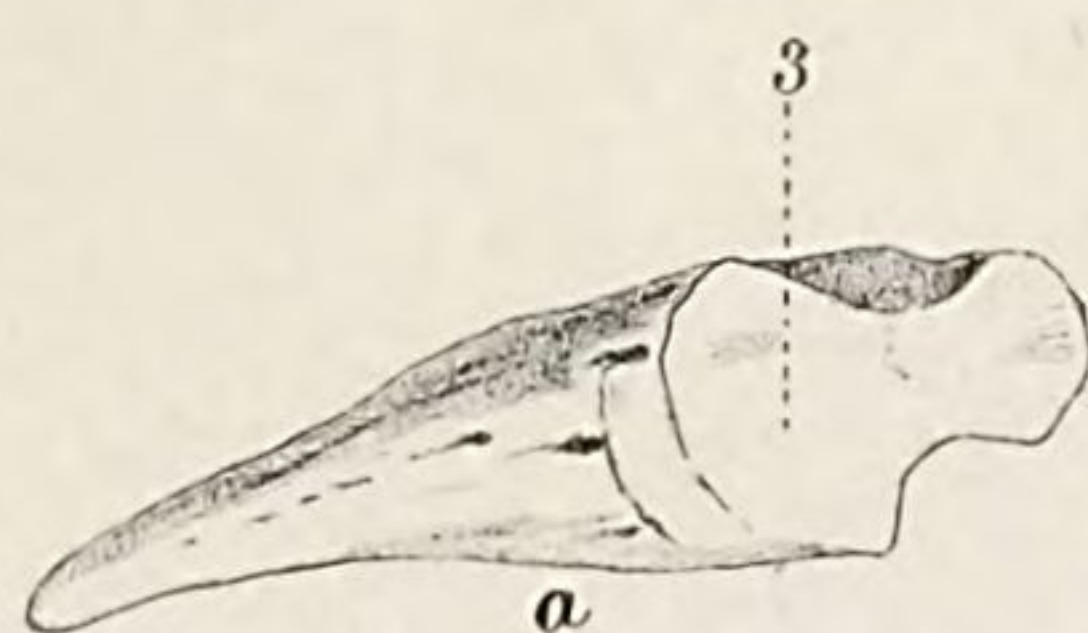


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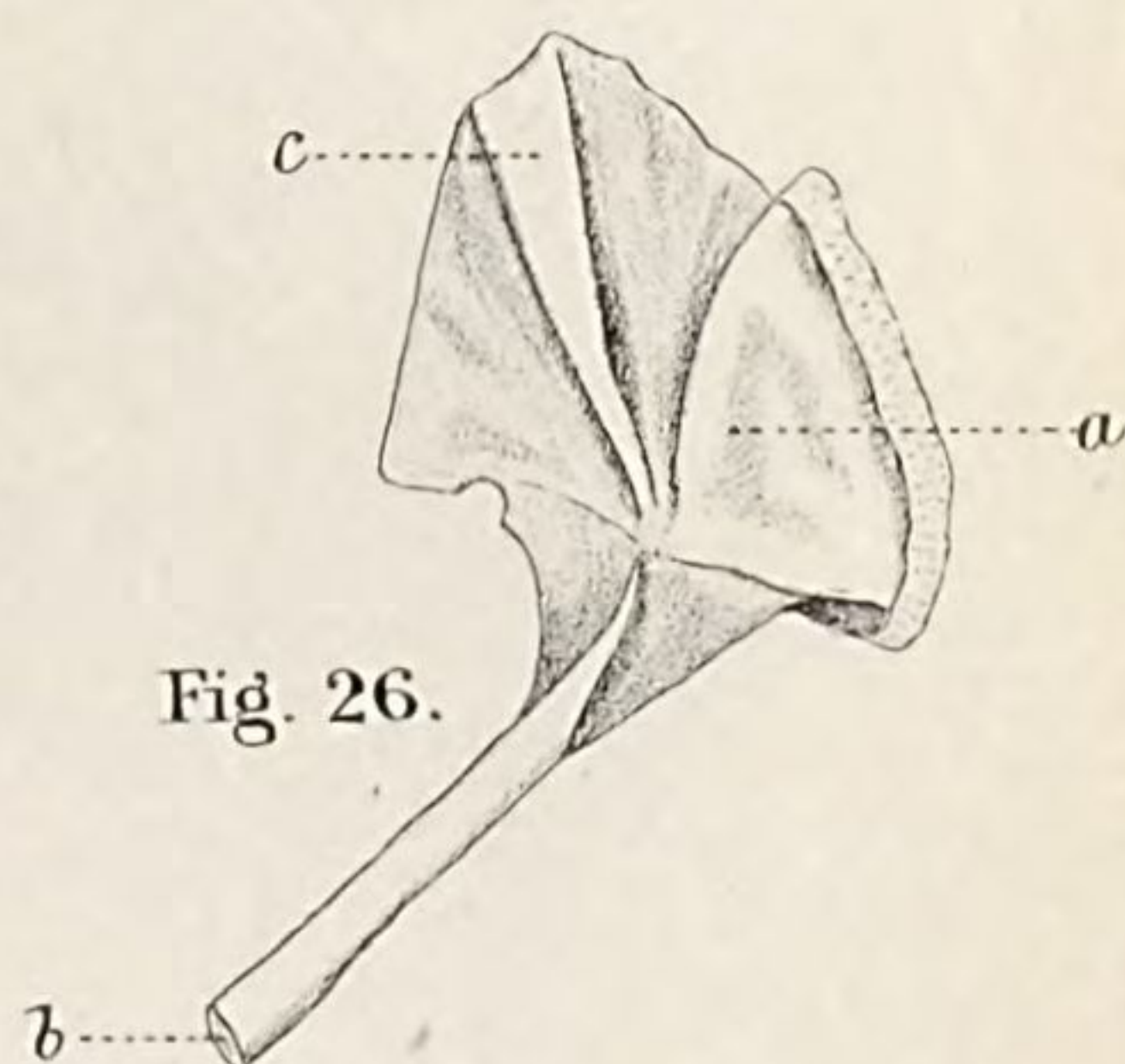


Fig. 24.

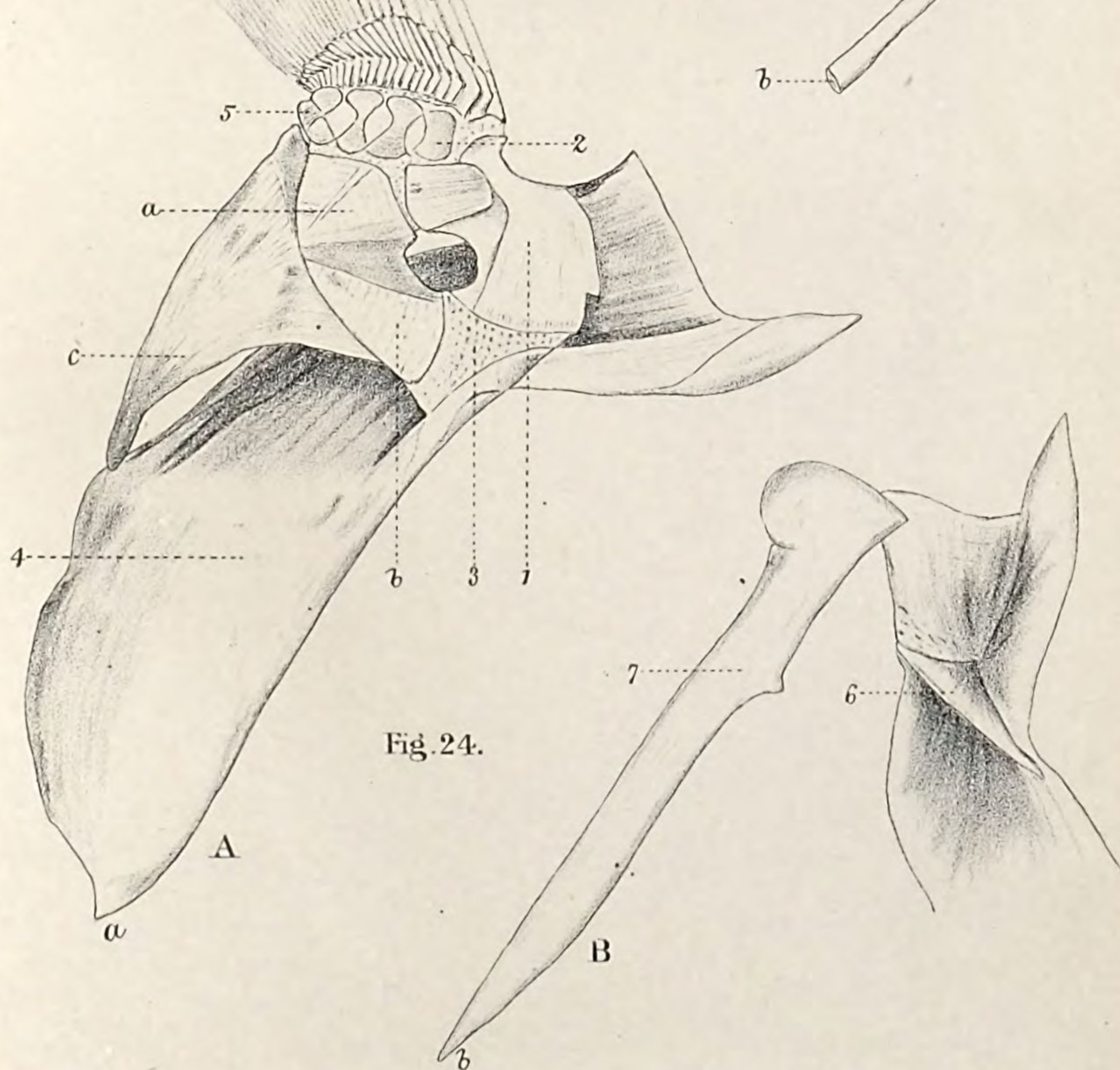
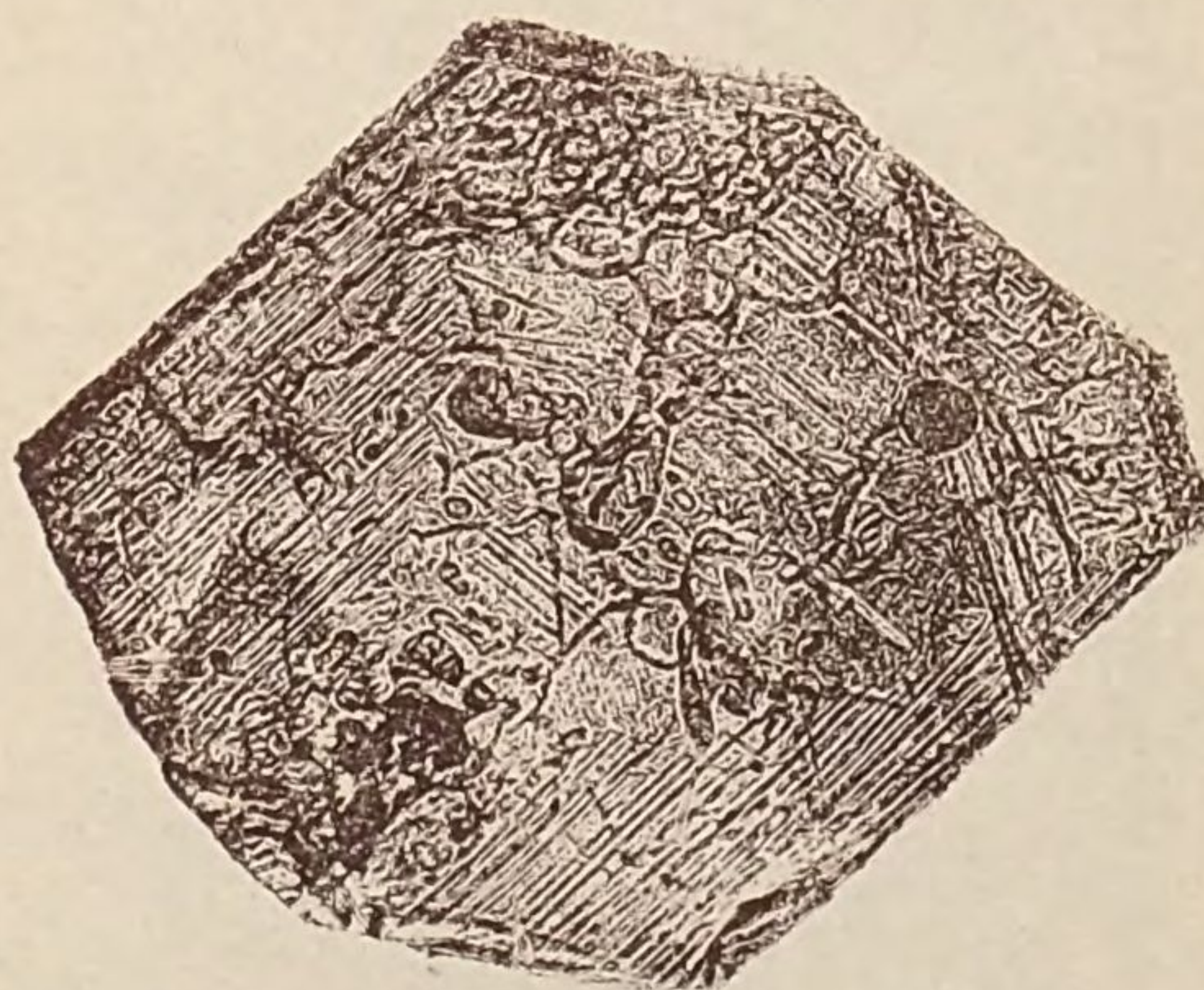
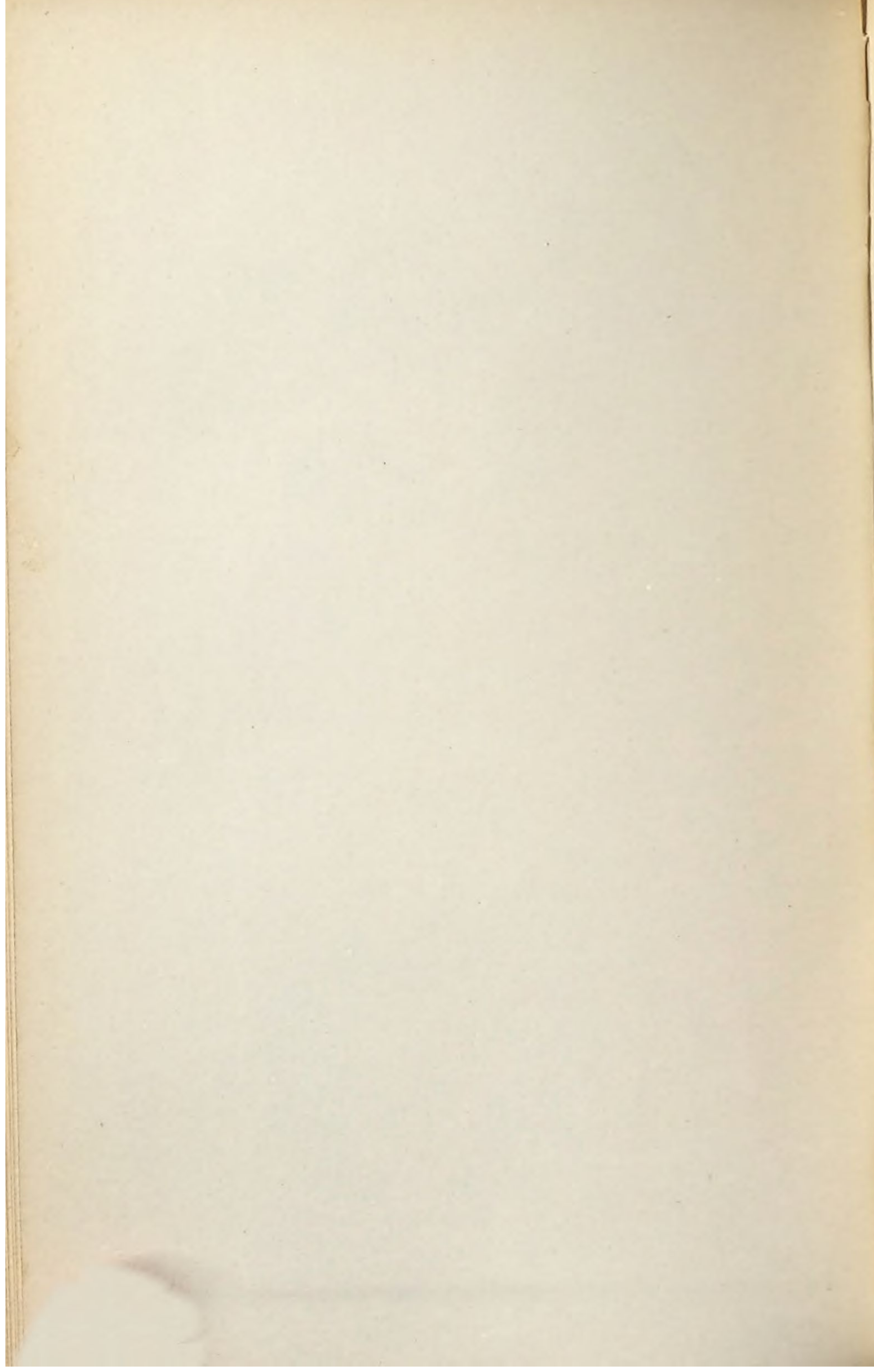




Fig.1.

Fig 2.





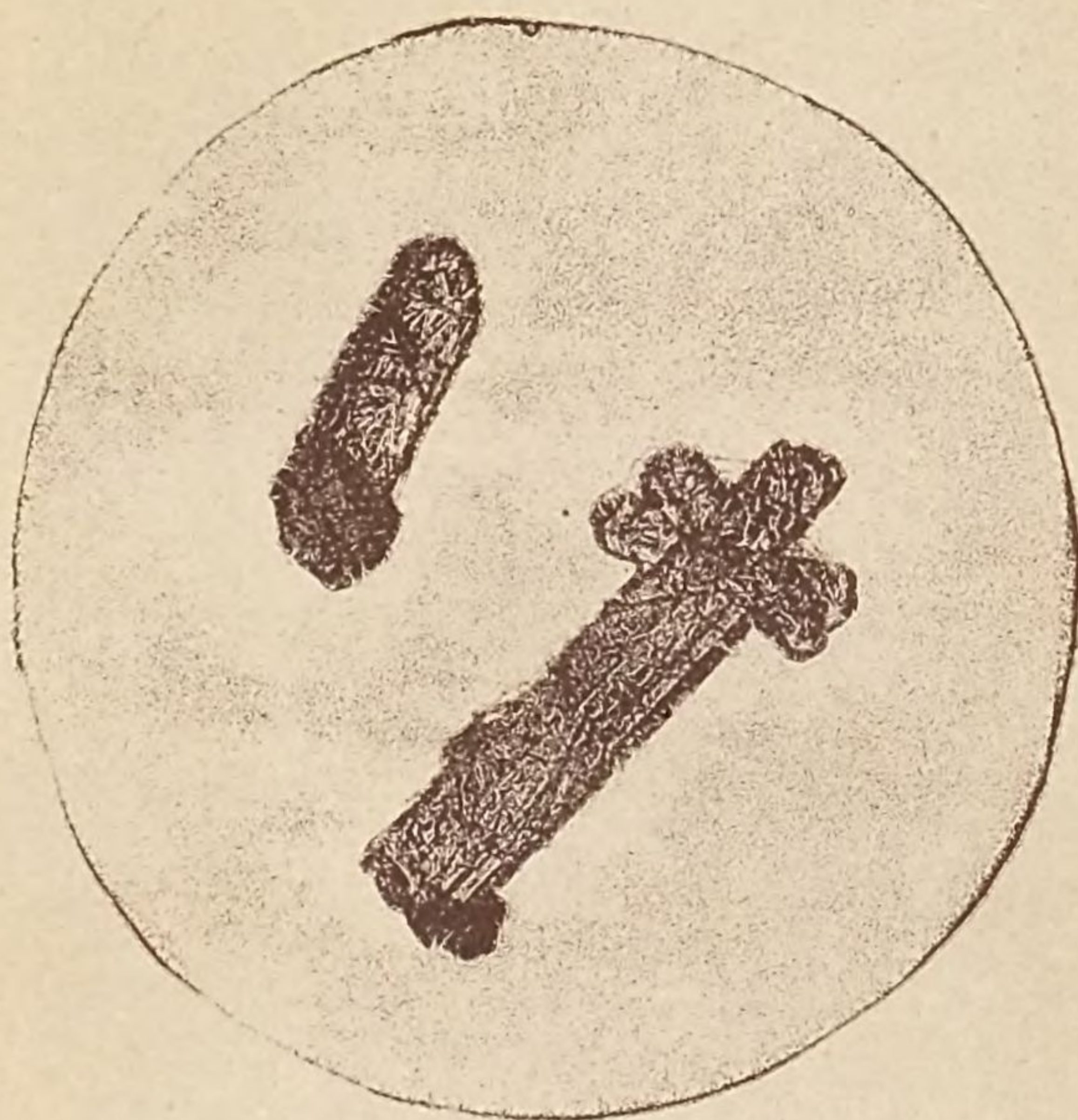


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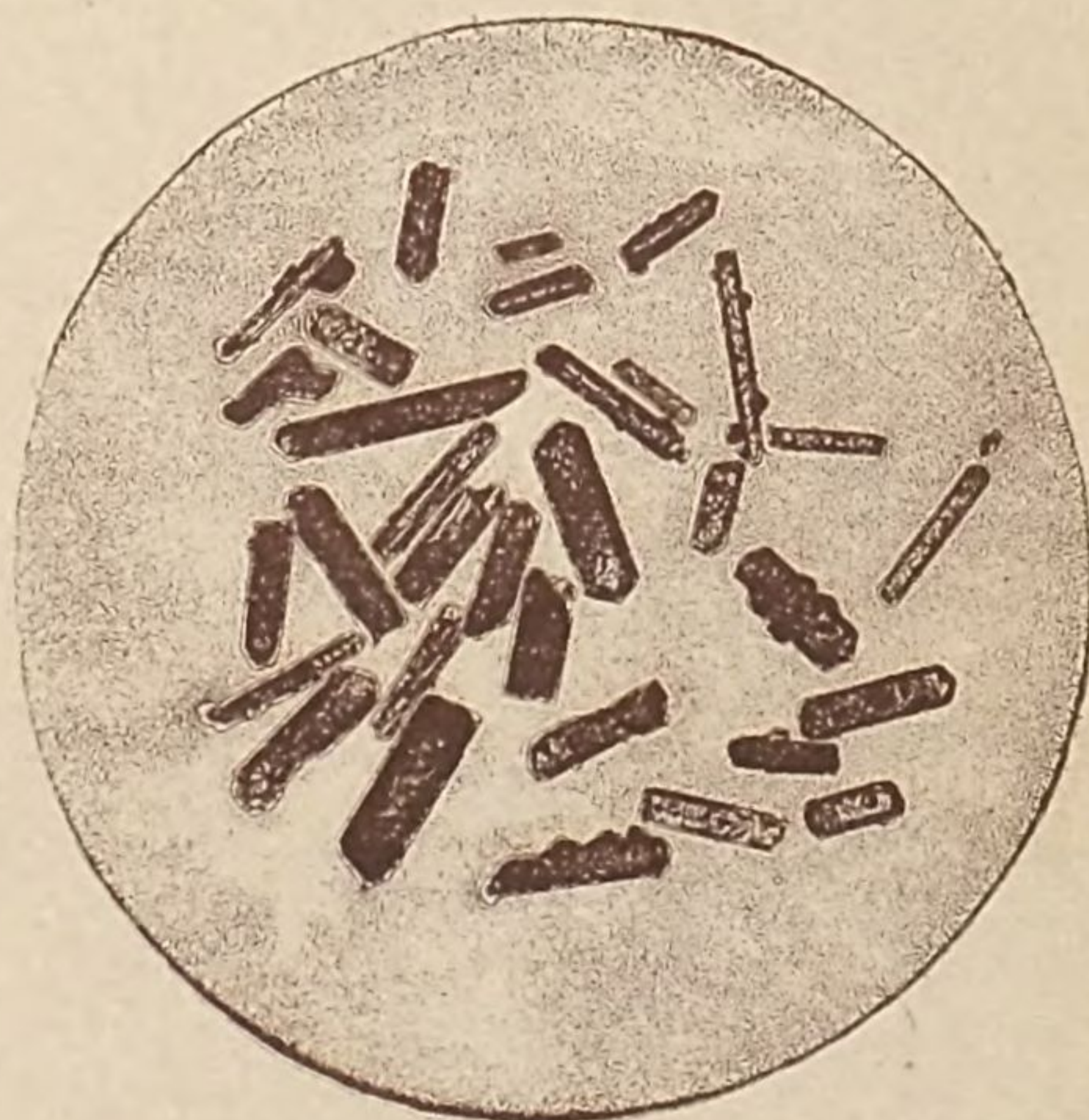
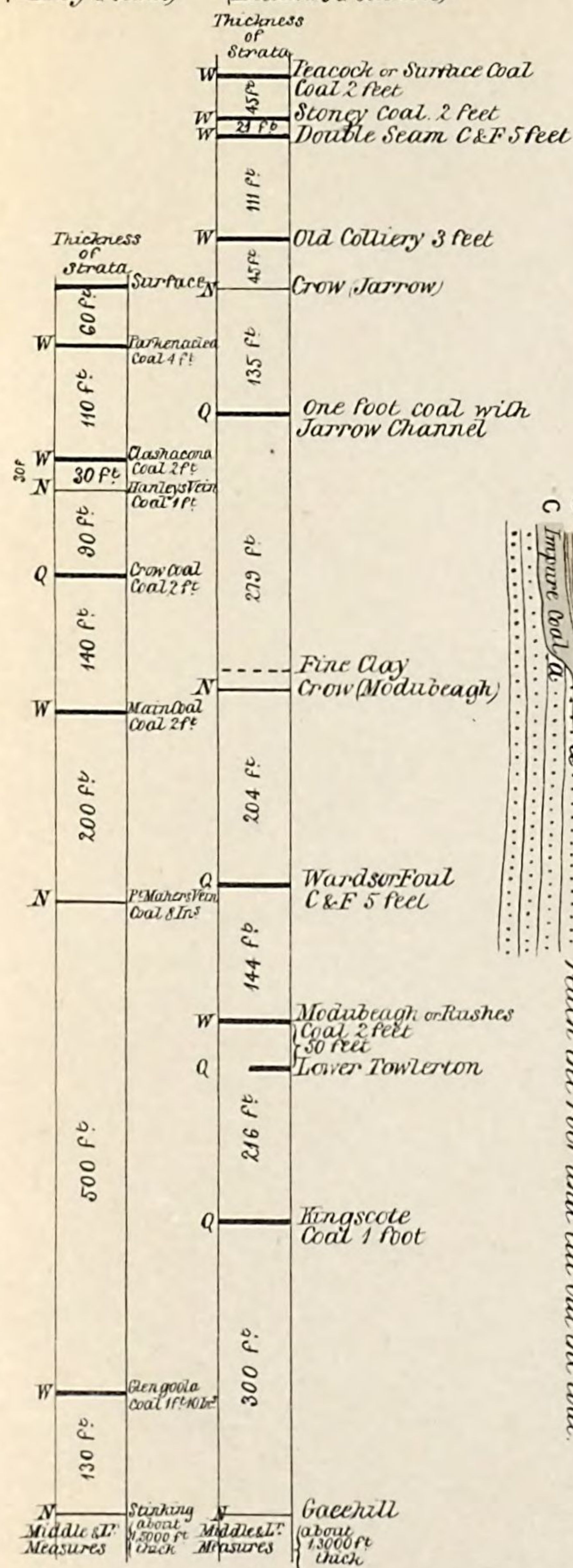


Fig. 4.

Section No 1.
Tipperary
(O'Kelly & Jukes)

Section No 2.
Leinster
(Meadows & Sutcliffe)



Index of Coal
W Workable
N Not Workable
Q Questionable

Horizontal Scale 132 ft to 1 Inch
Vertical " 20 " " "

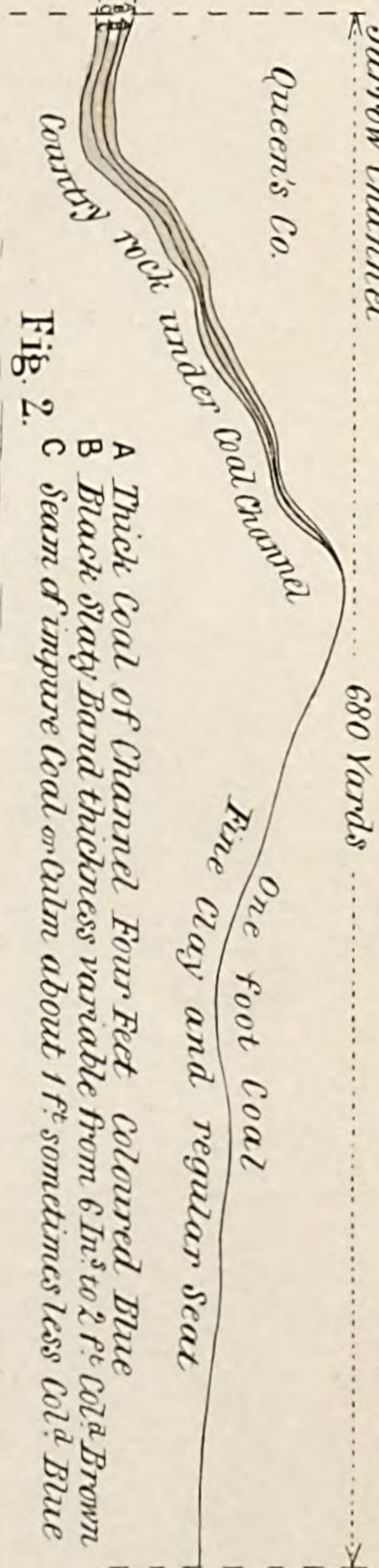
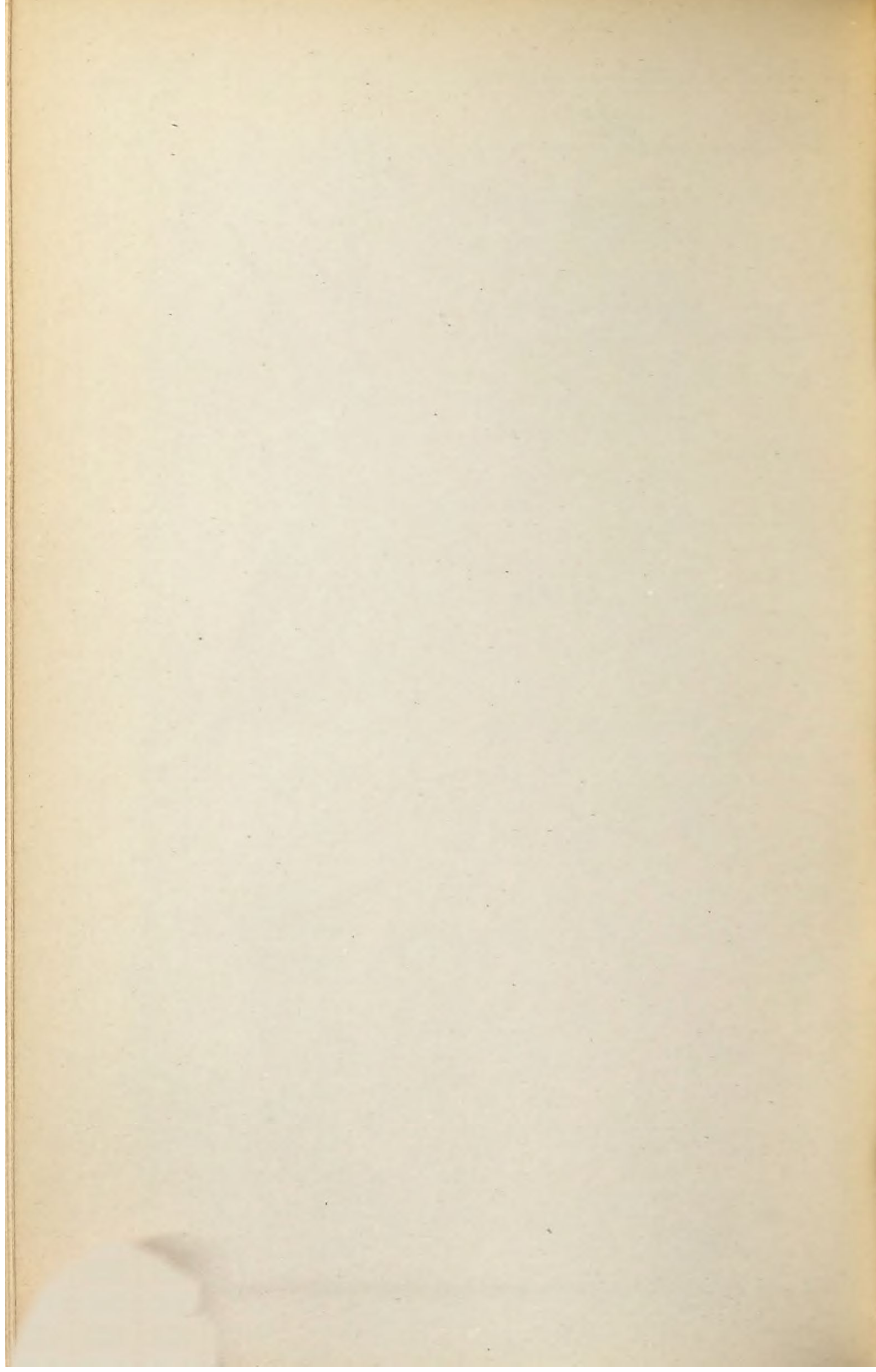
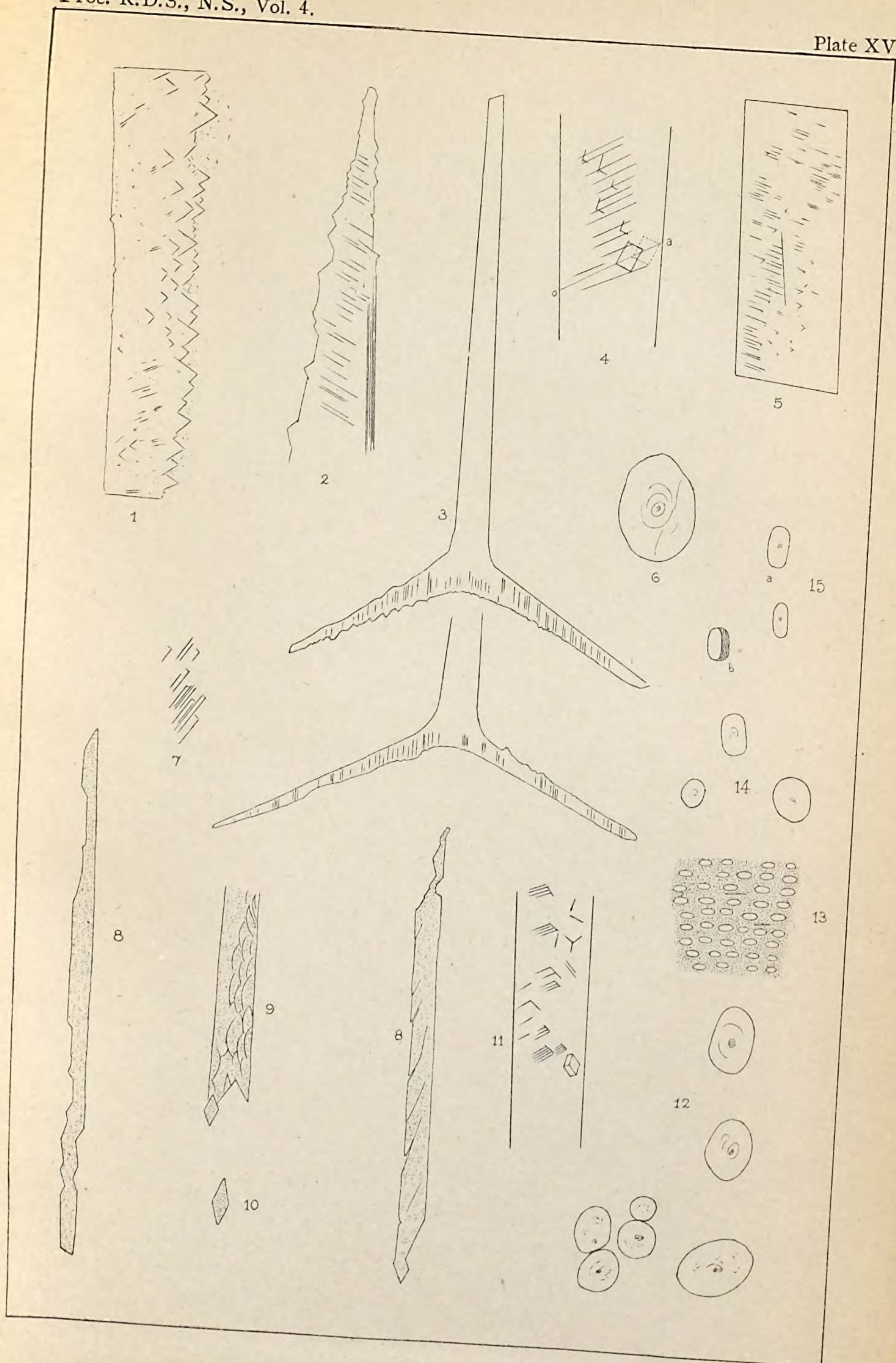


Fig. 1.
Jarrow Channel and the One foot Coal (Queen's Co. portion from Mr. Meadows's Working Section.)







1



2



3



4



5



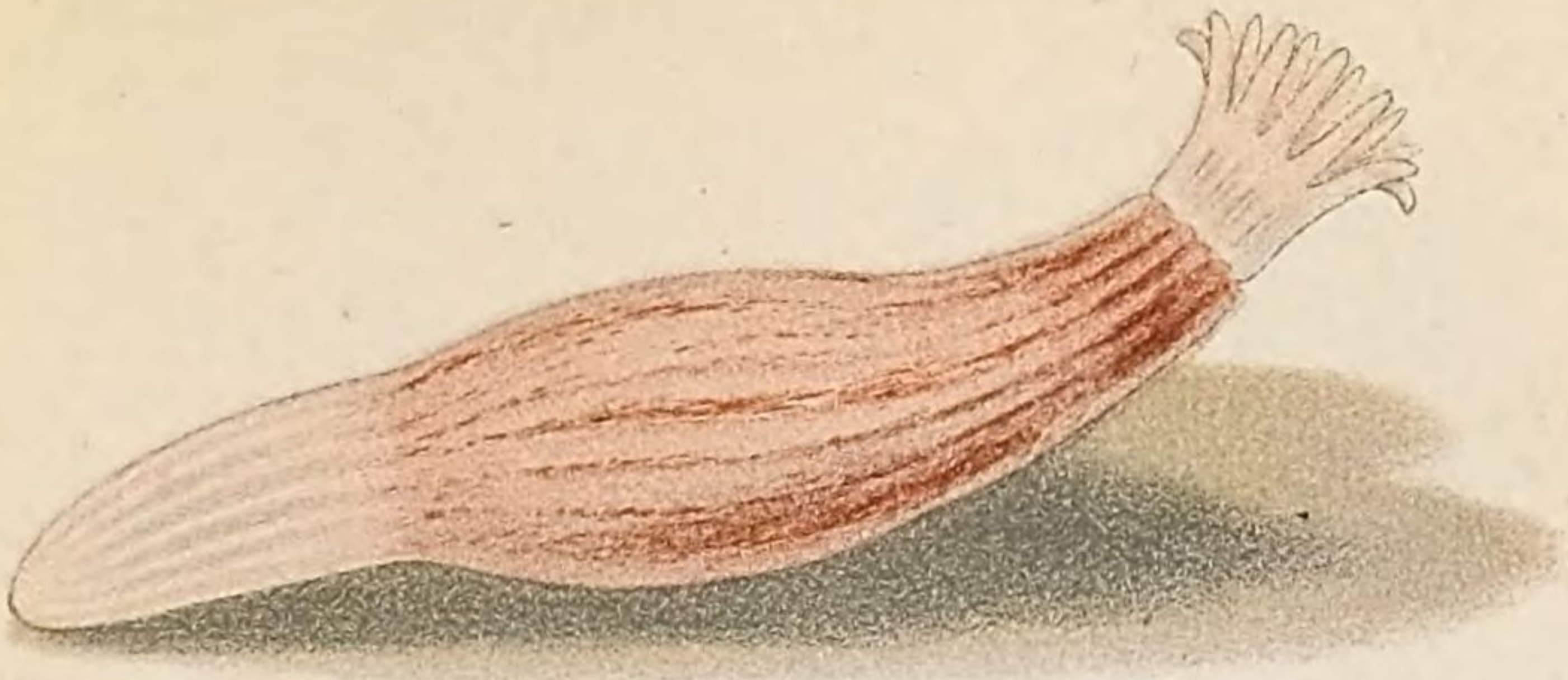
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7



8



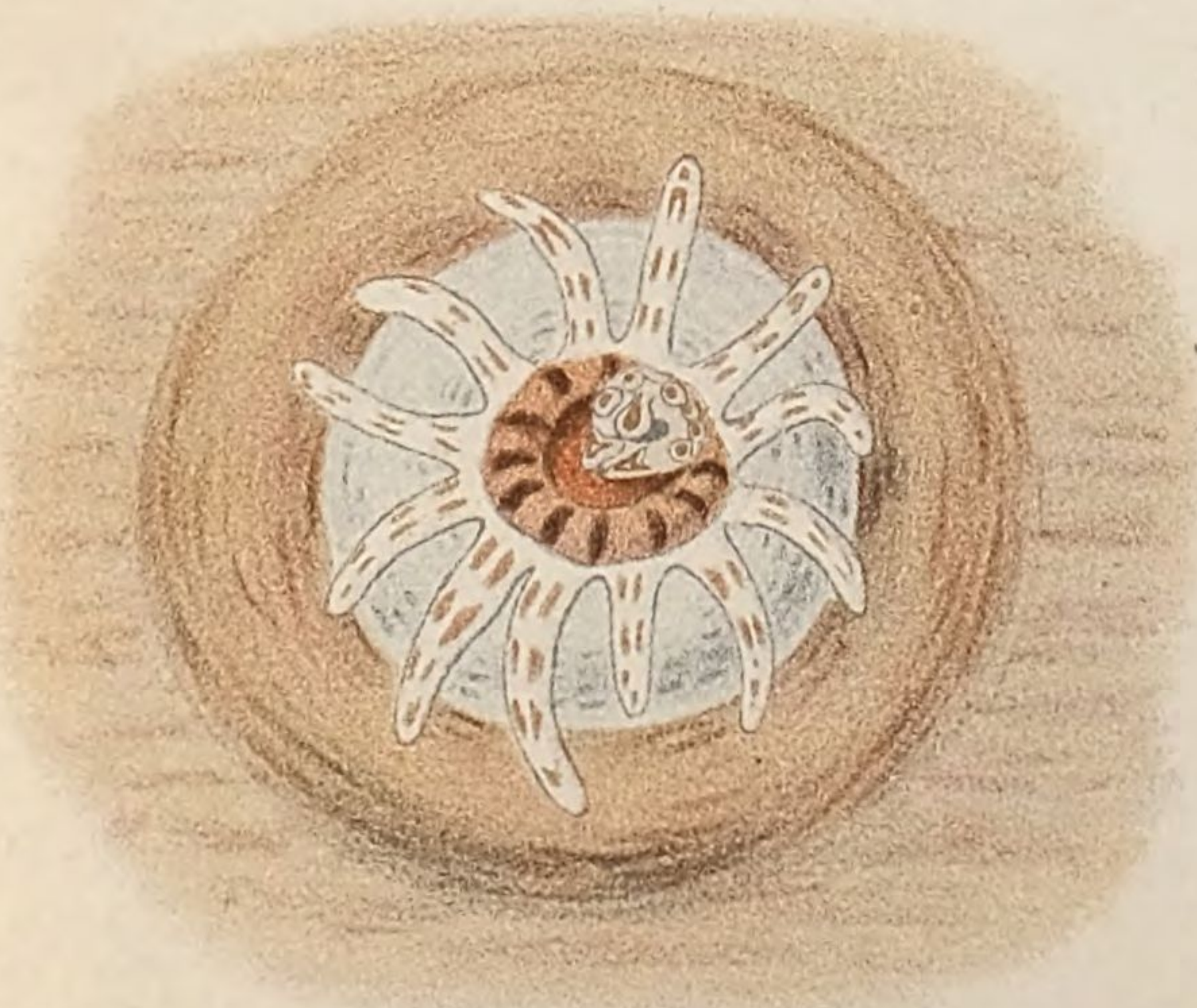
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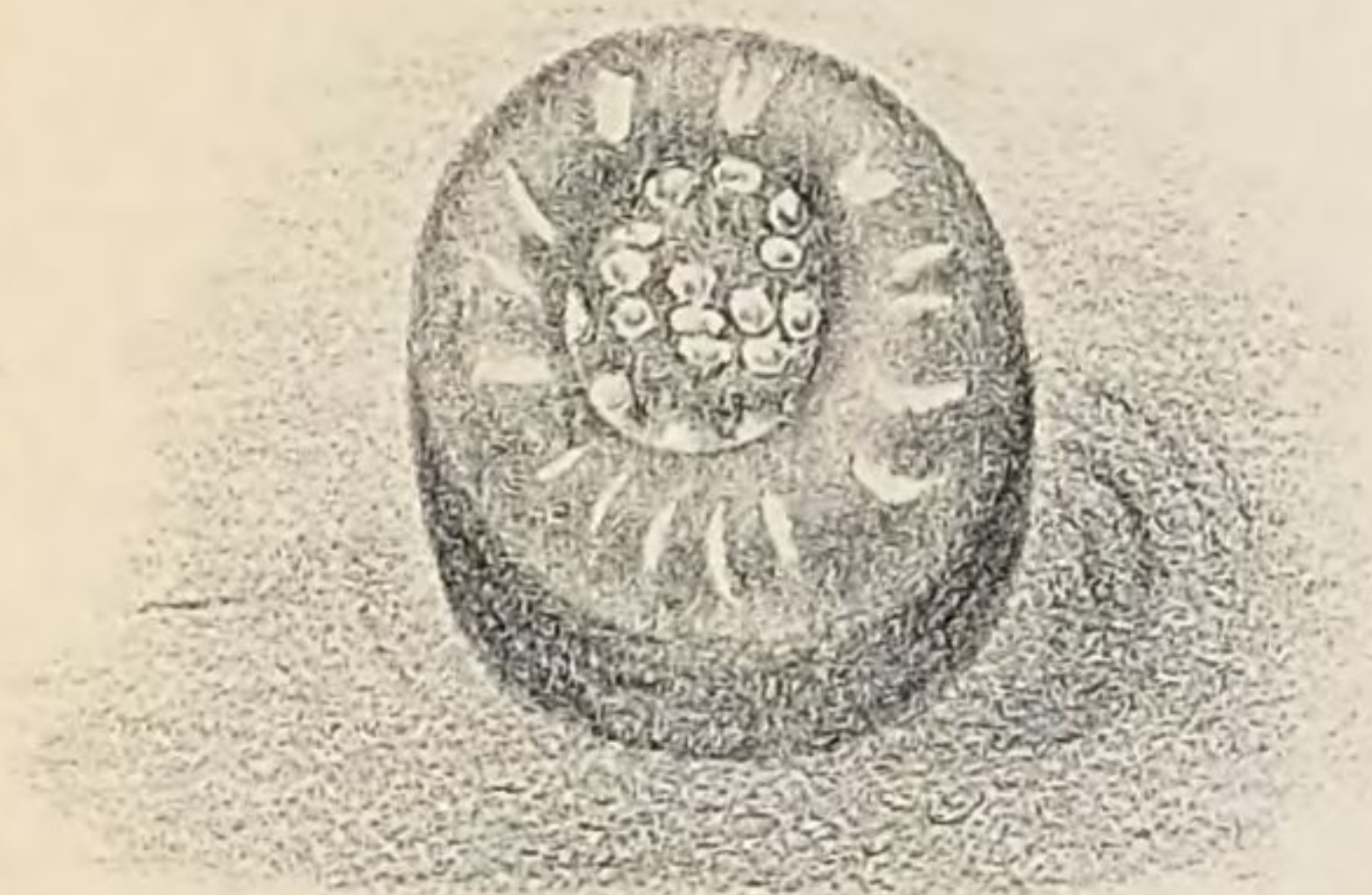
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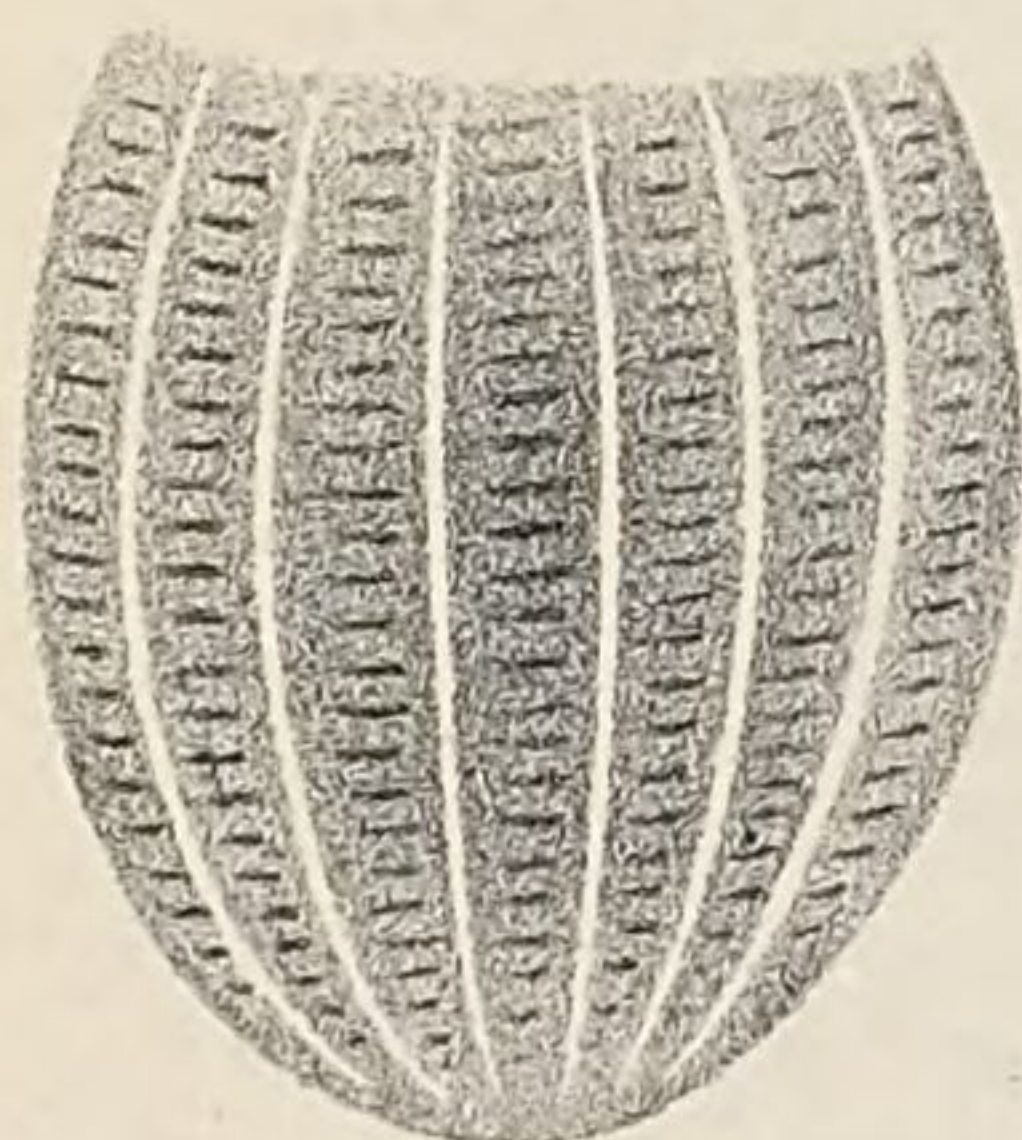
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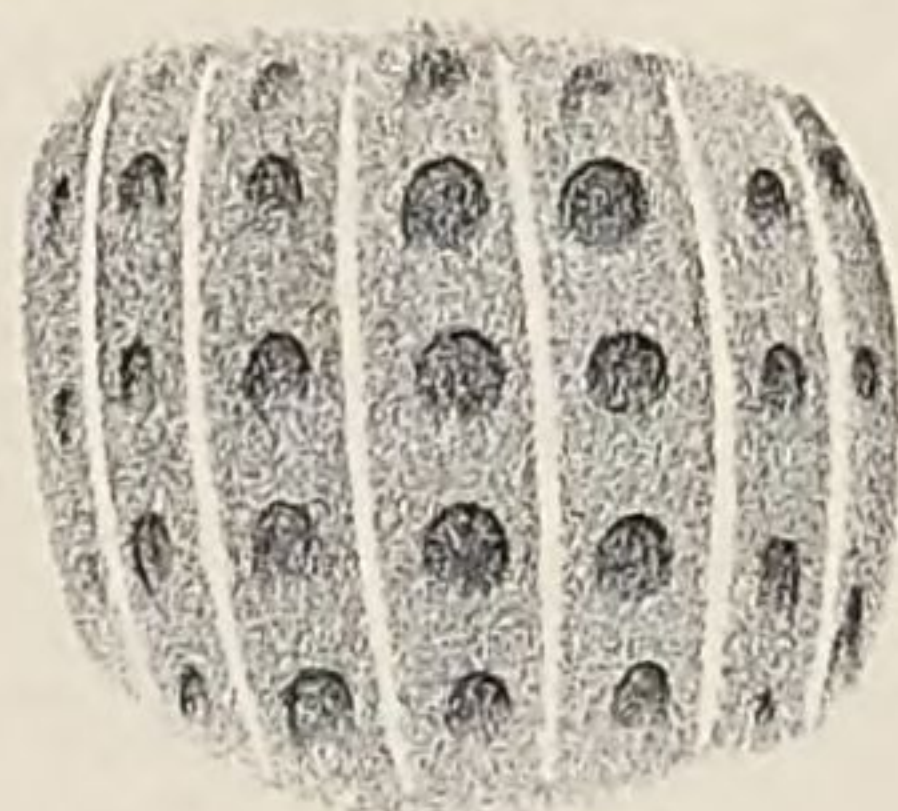
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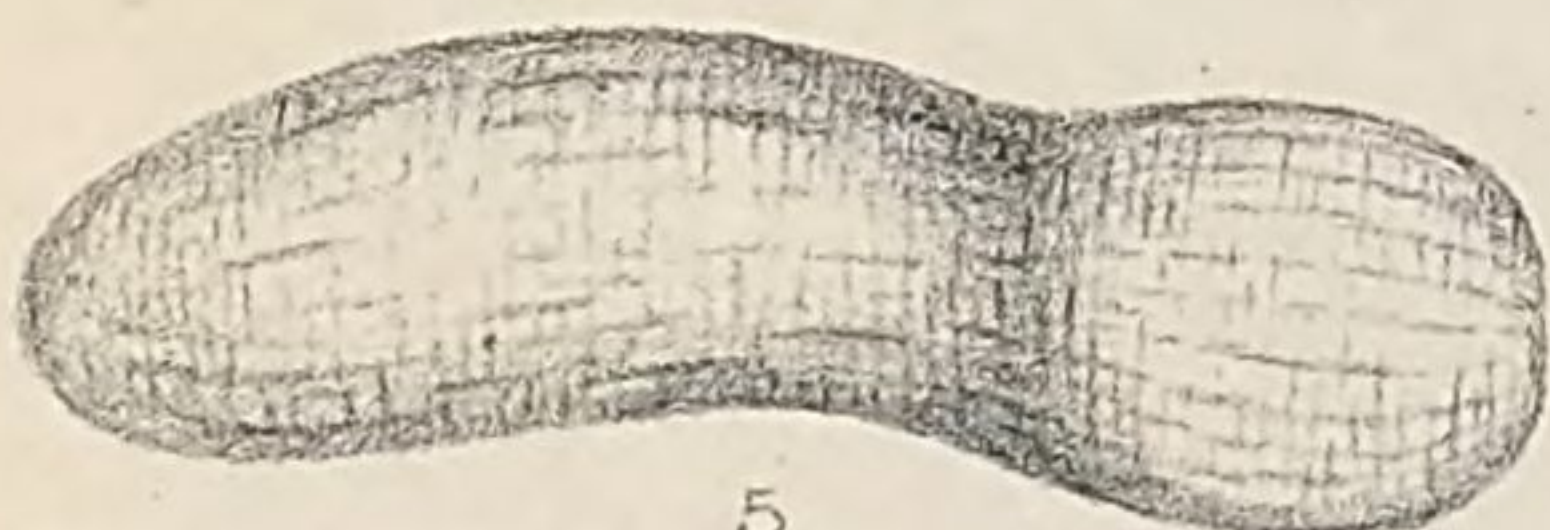
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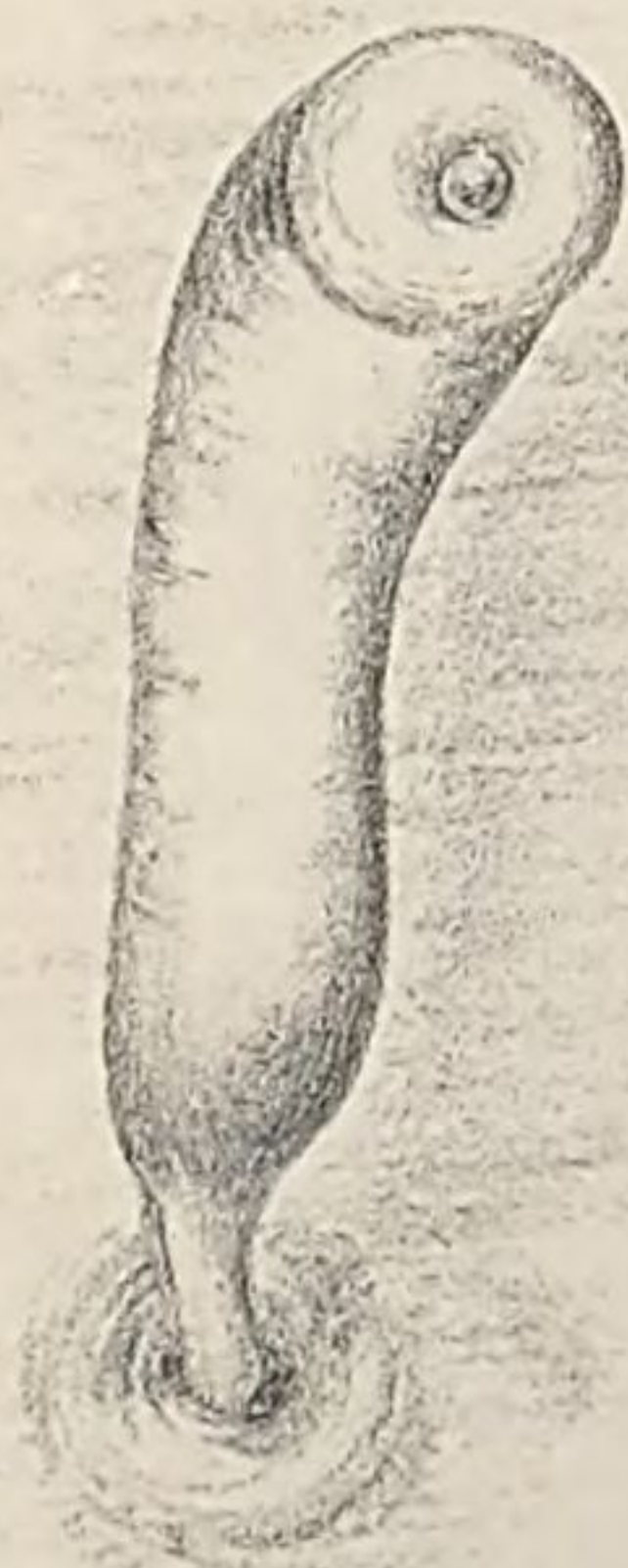
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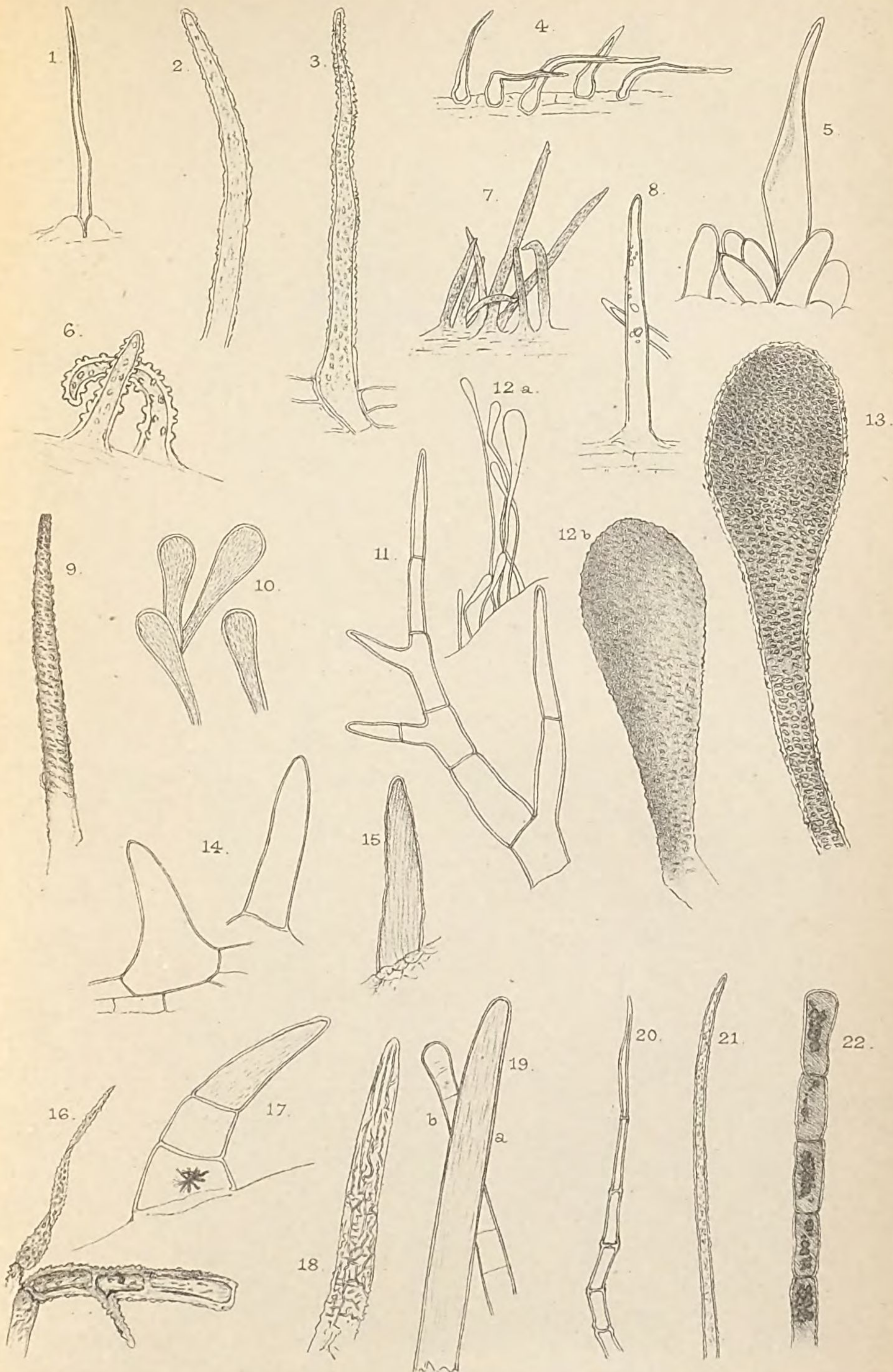
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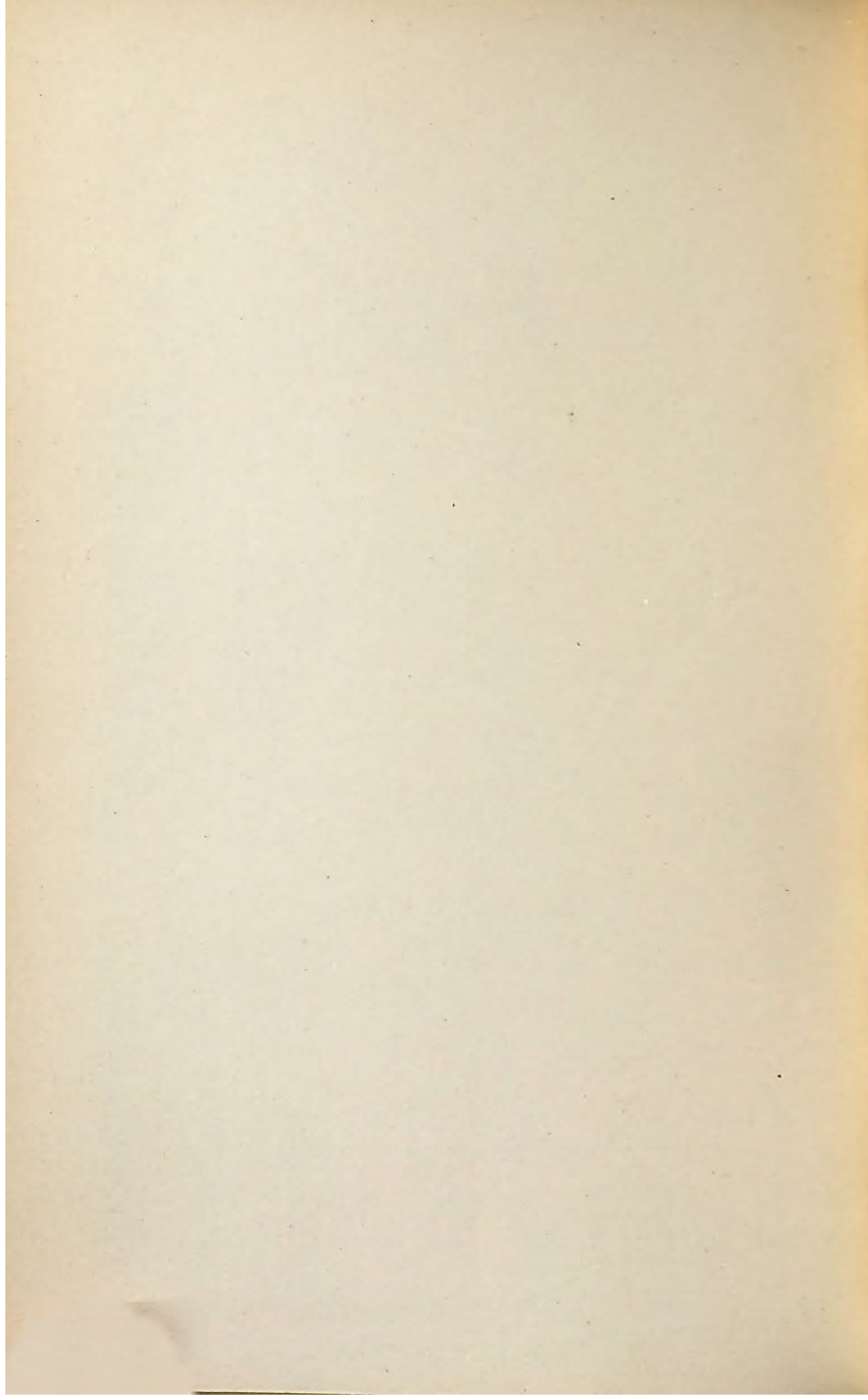


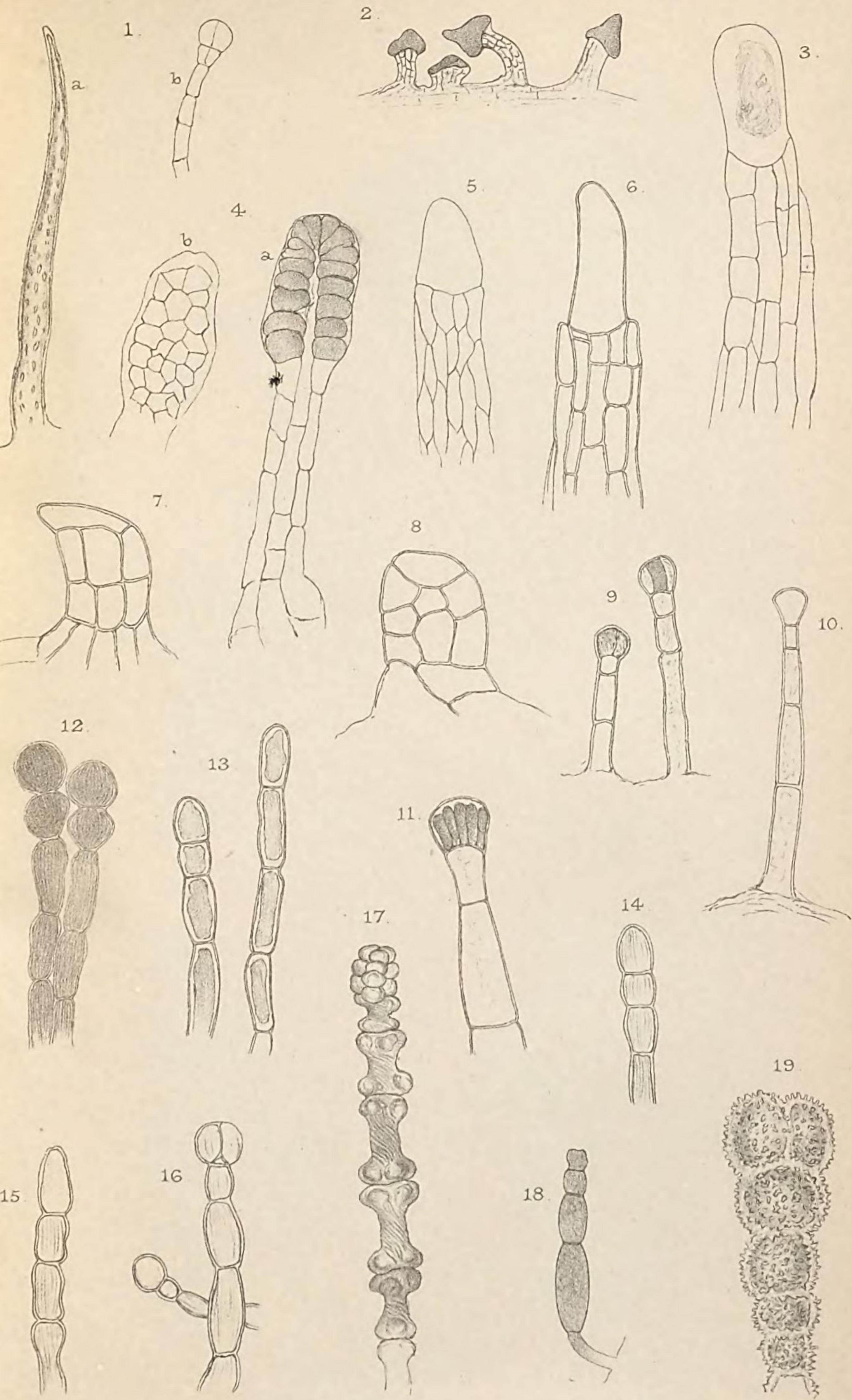
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STAMEN HAIRS.

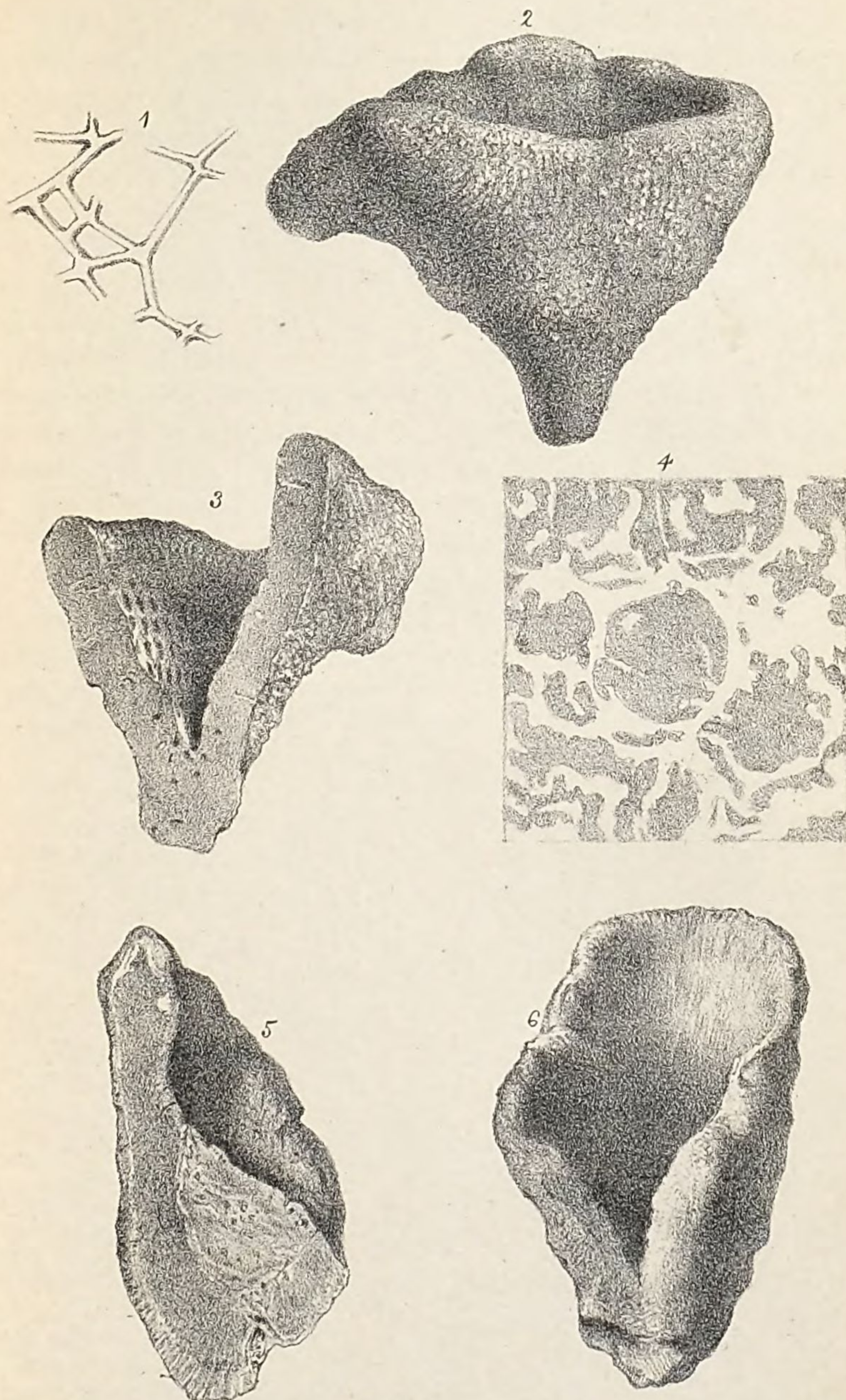
West, Newman & Co lith.

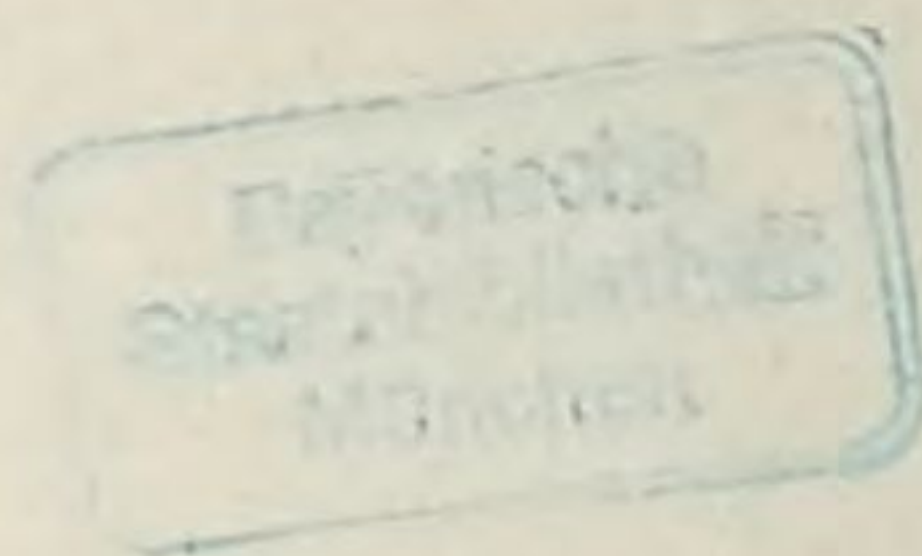




STAMEN HAIRS.

West, Newman & C^o lith.





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APRIL, 1883.

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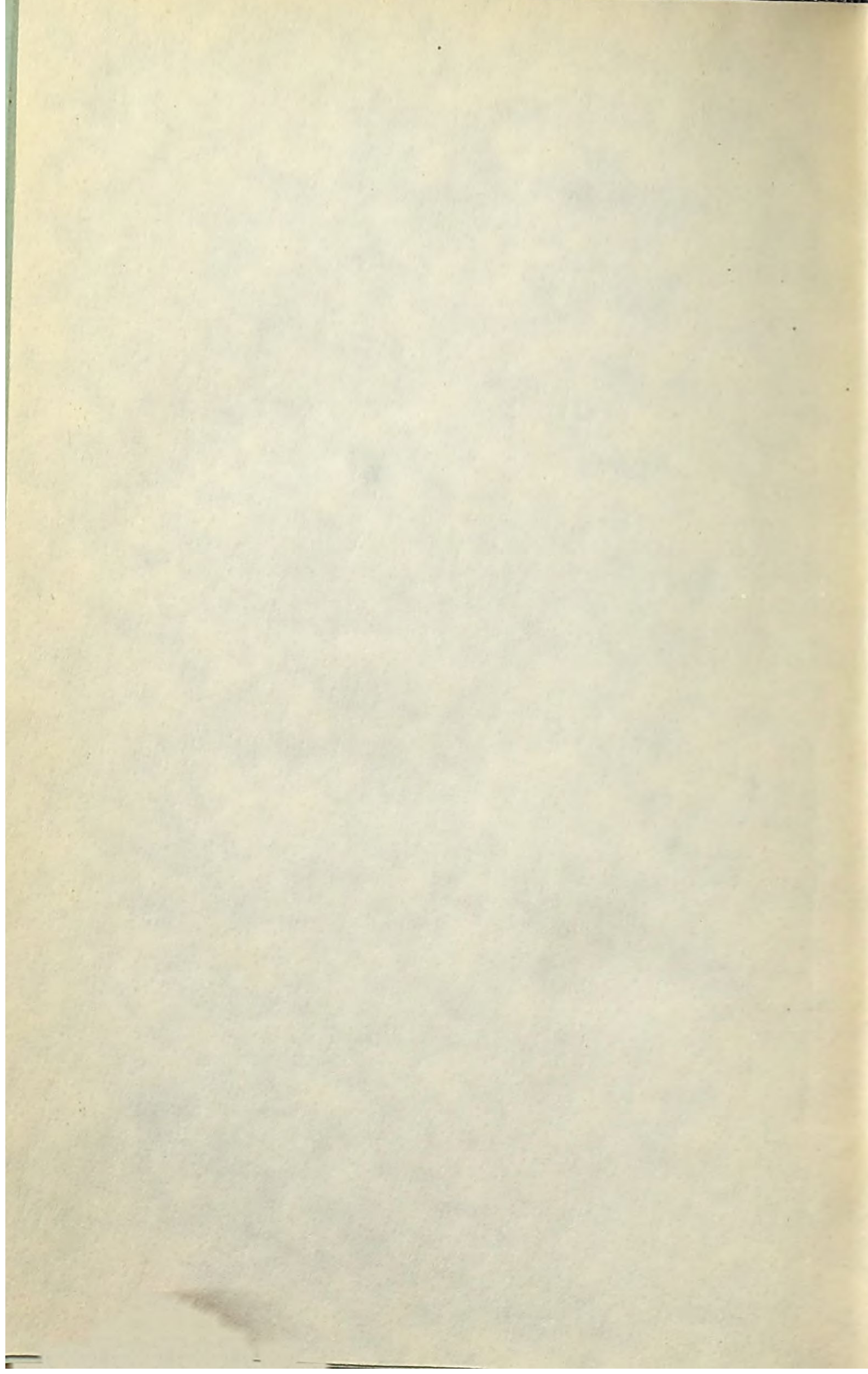
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